21829

NATIONAL LIBRARY
OTTAWA

CANADA

BIBLIOTHÈQUE NATIONALE
OTTAWA

NAME OF AUTHOR... Robert ... K. ... Hand .....

TITLE OF THESIS... Cubed ... Complete ... Rations .....

... and ... Fababeans ... for ... Dairy ...

... Cattle .....

UNIVERSITY... of ... Alberta .....

DEGREE FOR WHICH THESIS WAS PRESENTED... M.Sc. .....

YEAR THIS DEGREE GRANTED... Fall, 1974 .....

Permission is hereby granted to THE NATIONAL LIBRARY OF CANADA to microfilm this thesis and to lend or sell copies of the film.

The author reserves other publication rights, and neither the thesis nor extensive extracts from it may be printed or otherwise reproduced without the author's written permission.

(Signed). Robert K. Hand .....

PERMANENT ADDRESS:

... Box ... 653 .....

... Lacombe, Alberta ...

.....

DATED.. October ... 11 1974

NL-91 (10-68)

THE UNIVERSITY OF ALBERTA

CUBED COMPLETE RATIONS AND FABA BEANS FOR DAIRY CATTLE

BY

© ROBERT KEITH HAND

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

FALL, 1974

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Cubed Complete Rations and Faba Beans for Dairy Cattle"

submitted by Robert Keith Hand, B. Sc. (Ag.),

in partial fulfilment of the requirements for the degree of Master of Science

G. N. Hume

Supervisor

Elizabeth A. Dorrell

Gary Mathison

DATE October 1, 1974

ABSTRACT

Holstein cows were fed rations in 3 physical forms; loose concentrate plus hay, complete cubes plus loose concentrate and hay, and complete cubes. The complete cubes (60 per cent alfalfa hay and 40 per cent of a concentrate mixture) were 3/4" in diameter and 1 to 2 inches in length. Faba beans were compared to rapeseed meal as the source of supplemental protein. The concentrate mixture was maintained at 14 per cent crude protein by substitution of rapeseed meal and some barley by faba beans (Vicia faba L. vars minor). Digestion studies were conducted with 4 cows fed each ration. Milk production and composition was recorded.

Before parturition, most cows ate the cubes well. Some cows 5 to 10 days postpartum, went off-feed and were switched to loose concentrate and chopped hay to regain feed intake. Older, higher producing cows with higher feed requirements seemed more prone to off-feed difficulties than younger, lower producing cows with lower feed requirements. Cows later in their lactation consumed the cubes more consistently.

There were no significant differences ($P > 0.05$) in digestibility coefficients between rapeseed meal and faba bean rations. For loose concentrate plus hay, cubes plus loose concentrate and hay, and complete cubes, digestibility coefficients were 68.5, 64.9, and 62.8, respectively for dry matter ($P > 0.05$), 70.0, 70.1, and 68.9, respectively for crude protein ($P > 0.05$), and 69.4, 65.6, and 62.9, respectively for gross energy ($P < 0.05$). The coefficient of digestibility of gross energy in the loose concentrate plus hay ration was significantly different ($P < 0.05$) from that in the complete cubed ration.

Actual and 4 per cent fat-corrected milk production were not

significantly different ($P > 0.05$) from cows fed rapeseed meal or faba beans in the loose concentrate plus hay rations. Percentage fat was significantly higher ($P < 0.05$) in milk from cows fed faba beans than from cows fed rapeseed meal in the first 6 weeks of lactation (3.64 vs 3.11 per cent). In the first 16 weeks of lactation, the percentage fat in milk was 16.8 per cent higher ($P > 0.05$) from cows fed faba beans as compared with cows fed rapeseed meal (3.61 vs 3.09 per cent). Percentages of solids-not-fat and protein in milk, were slightly higher ($P > 0.05$) for cows fed rapeseed meal than those fed faba beans. Dry matter and digestible energy intake per day was not significantly different ($P > 0.05$) between cows fed rapeseed meal or faba beans.

A second experiment was conducted using growing heifers and bulls to test the acceptability of feed and seed grade faba beans at 0, 20, and 40 per cent levels of a barley ration. Heifers and bulls had average initial weights of 280 and 220 kg., respectively.

Dry matter intake and average daily gain were not significantly different ($P > 0.05$) between treatments. However, heifers, due to their larger weight, consumed significantly more ($P < 0.05$) dry matter daily than the bulls. At the 40 per cent level of faba beans, animals consumed 11.3 per cent more dry matter daily; at the 20 per cent level, dry matter intake was similar to that with the barley ration. The 20 and 40 per cent levels of faba beans resulted in 6.7 and 14.4 per cent, respectively, more average daily gain than with the barley ration. The 20 and 40 per cent levels of faba beans improved conversion of digestible energy by 13.9 and 14.4 per cent, respectively, over the barley ration.

ACKNOWLEDGEMENTS

It is a pleasure to thank all those who have given me their assistance in completing this project. I thank Dr. L. P. Milligan, Chairman of the Department of Animal Science, for placing the facilities of the Department at my disposal. The assistance and guidance of Dr. C. M. Grieve, Associate Professor of Animal Nutrition, was greatly appreciated during the course of this study, and in the preparation of the manuscript.

The friendly assistance and co-operation that I received from the staff at the Dairy Research Unit during the experiment was greatly appreciated.

The author also wishes to thank Dr. R. T. Hardin, Associate Professor of Poultry Genetics, for his statistical advice.

The patience and encouragement I received from Sandy was appreciated and acknowledged.

Financial support was provided by the National Research Council and by the Alfalfa Processors Co-op Association (Alberta) Ltd.

TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
REVIEW OF LITERATURE	2
RAPESEED MEAL FOR DAIRY COWS	2
Rapeseed Meal for Milk Production	2
Rapeseed Meal Acceptability	3
Rapeseed Meal and Urea	4
THE FEEDING OF FABA BEANS	5
Botanical Identification	5
Feeding Faba Beans to Ruminants	5
Feeding Faba Beans to Swine	7
Feeding Faba Beans to Poultry	8
REGULATION OF FEED INTAKE IN RUMINANTS	9
Physical Regulation	9
Physiological Regulation	10
EFFECT OF FEEDING PELLETED, CUBED AND WAFERED RATIONS	11
Factors Affecting Nutritive Value	12
Physical Form of Roughage	13
Digestive Differences	13
Changes in pH and VFA Concentrations	15
Differences in Digestion Coefficients	16
Rate of Passage	18
Energy Retention	19
Pelleting High Quality Rations	20
Pelleting Complete Rations	22
Increased Intake by Pelleting	23
MILK PRODUCTION BY COWS FED PELLETS, CUBES, OR WAFERS	25
Pellets	25
Wafers	28
Cubes	30
THEORIES ON MILK FAT DEPRESSION	31
Reduction of Acetic Acid	31
Reduction of B-Hydroxybutyric Acid	32
Endocrinological Control of Fat Mobilization	33
Methods of Maintaining Milk Fat	35
EXPERIMENTS AT THE UNIVERSITY OF ALBERTA	37
Introduction	37

TABLE OF CONTENTS

	PAGE
Experimental	37
Experiment 1	37
Design	37
Experimental Rations	38
Animal Management	39
Digestion Studies	40
Milk Samples	41
Statistical Analysis	41
Experiment 2	42
Experimental Rations	42
Animals and Management	42
Statistical Analysis	43
RESULTS AND DISCUSSION	44
Rapeseed Meal Versus Faba Beans as a Protein Supplement	44
Feed Intake on Cubed Rations	45
Faba Bean Cubes Plus Concentrate and Hay	45
Rapeseed Meal Cubes Plus Concentrate and Hay	48
Faba Bean Cubes	49
Rapeseed Meal Cubes	50
Alfalfa Cubes	50
Complete Cubed Rations	51
Coefficients of Apparent Digestibility	52
Experiment 2 Faba Bean Acceptability	56
Dry Matter Intake	56
Average Daily Gain	56
Feed Conversion Efficiency for Dry Matter and Digestible Energy	56
SUMMARY	60
Experiment 1	60
Experiment 2	61
CONCLUSIONS	63
BIBLIOGRAPHY	64
APPENDIX	

LIST OF TABLES

Table	Description	Page
1	Concentrate Mixtures	39
2	Ration Formulation	42
3	Rapeseed Meal vs. Faba Beans as a Protein Supplement	46
4	Feed Intake of Cows Later in Lactation	51
5	Coefficients of Apparent Digestibility	55
6	Results of Treatments and Sex for Growing Bulls and Heifers	58
7	Ration Analysis and Requirements and Energy Intake by Growing Bulls and Heifers	59
Appendix Table A	Mean Squares (Experiment 1)	72
Appendix Table B	Mean Squares (Experiment 2)	74
Appendix Table C	Treatment-Sex Interaction (Experiment 2)	75
Appendix Table D	Faba Bean Composition	76

INTRODUCTION

Present trends to increase mechanization of the feeding of dairy cattle are resulting in experimental work to determine whether or not various "packaged feed units" can maintain or increase the nutritive value of feed. Completely pelleted or cubed rations can have definite advantages in preventing the sorting of ingredients, allowing easier handling and storage, reducing dust, and permitting adaptation to mechanical or self-feeding methods. Disadvantages of pelleting and cubing include the high cost of pelleting and cubing and the high cost of hauling bulky roughage to pelleting mills.

In addition to investigations of the physical form of the feed, research on protein supplements is needed for western Canadian feedlots and dairy operations with the object of replacing imported protein supplements, such as soybean meal and fish meal, with the products that can be produced locally. One new protein source in Western Canada is the field bean or faba bean (Vicia faba L. vars. minor). Little work on feeding faba beans to ruminants has been carried out in Canada yet, although literature is available from European research.

Therefore, an experiment was undertaken to test the feeding of a completely cubed ration to dairy cows in comparison with a normal ration of chopped hay and concentrate in the form of a meal. In the experiment, faba beans were compared with rapeseed meal as protein supplements. Feed intake, digestibility of the rations, milk production, and milk composition were examined. In addition, a group of bulls and heifers, averaging 250 kg. liveweight, were fed faba beans as a protein supplement to study the acceptability of high concentrate rations, containing medium and high levels of the beans.

REVIEW OF LITERATURE

Rapeseed Meal for Dairy Cows

Rapeseed Meal for Milk Production

Jarl (1951) fed dairy cows 2.5 kg. of an oilcake mixture containing 0, 25, 50 and 60 per cent rapeseed meal. Some palatability problems giving reduced feed intake were reported at the beginning of the trial, but were overcome with an adjustment period to the feed. Milk production was less when the 50 and 60 per cent levels of the rapeseed meal were used, as compared to levels of 0 and 25 per cent. There was a small decrease in fat content of the milk with all combinations using rapeseed meal. Homb, Ørud, and Waldern (1958) and Nordfeldt (1958) also reported butterfat to be slightly lower from cows fed rapeseed meal.

In an experiment by Seale (1952), feeding a ration of either 20 per cent rapeseed meal or 20 per cent linseed meal resulted in similar milk production and equal butterfat content. There was no difference in palatability between rations, or taste and odor of milk produced. In work by Homb et al. (1958), the feeding of rapeseed meal as compared to linseed meal, both at the 5 per cent level, resulted in no significant difference in milk yield, general condition of animals or taint of milk. Other work by Homb et al. (1961), in which cows were fed either 5 or 10 per cent rapeseed meal in the concentrate mixture or an equivalent amount of herring meal or soybean meal, resulted in no difference in milk yield, fat content of the milk or weight gain of cows. Nordfeldt (1958) also reported no difference in quality or taste of milk when rapeseed meal was fed at 1.5 kg. per cow daily. The use of rapeseed meal resulted in higher milk production than with soybean meal.

Asplund (1961) fed milking cows rapeseed meal at the rates of

0, 10 and 20 per cent of the dry matter content of the ration. Linseed meal was used as the control at the same protein levels. Cows that received 10 per cent rapeseed meal produced as much milk as those receiving linseed meal, but those receiving 20 per cent rapeseed meal declined in milk production almost twice as fast as the control cows. Burgess and Nicholson (1971), feeding either 22.5 per cent rapeseed meal or 1.75 per cent urea compared to 15 per cent soybean meal, found feed intake and body weight gains similar, but milk production declined most rapidly for those cows fed urea; cows fed rapeseed meal declined more rapidly in milk production than those fed soybean meal. Ingalls, Waldern, and Stone (1970) also found daily milk production, persistency of milk production, and percentage milk fat lower for cows fed rapeseed meal than for those fed soybean meal. Ingalls et al. (1970) reported no difference in daily intake by cows fed concentrate rations containing either 24 per cent soybean meal or 27 per cent rapeseed meal.

Rapeseed Meal Acceptability

In other work by Asplund (1962), the use of 10 per cent linseed meal or 10 per cent rapeseed meal in the concentrate mixture resulted in no difference in milk production. He noted that rations containing rapeseed meal were as palatable as those containing linseed meal. In work by Witt, Huth, and Hartmann (1959), feeding cows concentrate containing 25 per cent rapeseed meal increased average daily milk yield per cow by 0.35 kg. with no adverse effects on the fat content or acceptability of the ration. Chomyszyn and Beza (1965), feeding rapeseed oil meal up to 50 per cent of the concentrate, found milk production increased by 1.4 kg. daily, with no change in acceptability of the ration. In other work (Interim Report to ARC, 1974), rapeseed meal fed at levels as high

as 15 per cent of a complete ration for dairy cows resulted in no signs of reduced feed intake, decreased palatability, decreased milk yield or change in composition of milk. The daily intake of rapeseed meal was as high as 3.0 kg. when fed as a component of a complete diet in this study.

Rapeseed Meal and Urea

Ingalls, Seale, and Mckirdy (1968), replaced 10 per cent soybean meal with 12 to 13 per cent rapeseed meal in dairy rations. They found concentrate intake to be reduced. Milk production, percentage butterfat, percentage solids-not-fat (SNF) and percentage protein were unaffected. When 6 per cent rapeseed meal and 0.8 per cent urea replaced the soybean meal, there was a reduction in feed intake similar to that obtained with the 12 per cent rapeseedmeal ration. In work by Grieve (1973), comparing 8.5 per cent rapeseed meal and 0.75 per cent urea to 14.5 per cent soybean meal in a ration fed to lactating dairy cows, it was found that 8.5 per cent rapeseed meal and 0.75 per cent urea could substitute entirely for soybean meal without depressing feed intake, milk protein percentage, or milk SNF percentage. Butterfat percentage and milk production were slightly lower with the ration containing rapeseed meal, but the difference was attributed to variation between cows.

Grenet (1970) studied the effects of feeding toasted rapeseed meal to dairy cows. He found toasting permitted greater utilization of rapeseed meal by increasing the acceptability of the meal. Addition of toasted meal to the level of 30 per cent of the ration increased feed intake. Larger additions reduced intake. An adaptation period was required for the meal. He recommended that the quantity of rapeseed meal be increased gradually.

In reviews by Ingalls and Waldern (1972) and Whiting (1965),

they reported rapeseed meal to be a good protein supplement for lactating dairy cows if the level of rapeseed meal did not exceed 10 per cent of the concentrate. At this level, there was no effect on feed intake or milk production.

The Feeding of Faba Beans

Botanical Identification

The species Vicia faba L. is divided into two subspecies, Vicia faba L. vars. minor being the small faba bean, tick bean or horsebean, and Vicia faba L. vars. maior being the broadbean. The difference between the tick bean and the horsebean is the larger size of the horsebean (Presber, 1972).

For terms of botanical identification, the subspecies Vicia faba L. vars. minor is within the class of the Dicotyledoneae being in the subclass Choripetalae (Presber, 1972). As the faba bean is in the Leguminosae order and is a common edible bean, it is in the Papilionaceae family and Viceae (vetches) subfamily of the genus Vicia (vetch). Vicia faba should be considered separate from the genus Vicia since it will not cross with any other Vicia species and there is no wild form of Vicia faba.

Feeding Faba Beans to Ruminants

Feeding faba beans to ruminants has proven successful in European research (Richter, Cranz, and Antoni, 1964; Huber, 1972; Antoni, 1964; Franck, undated). Faba beans are close to barley in terms of energy but are considerably higher in protein. As a general rule, in terms of biological value, 2 parts of faba beans can be replaced by 1 part feed grain and 1 part soybean meal (Huber, 1972). Franck (undated) emphasizes that 3 parts corn and 1 part faba beans, both in the whole

plant form, can supply good silage to fattening steers or pigs.

The feeding of faba beans to calves is limited by the beans bitter taste; 1/2 kg. per day of chopped faba beans being the limit (Antoni, 1964). The bitter taste is due to the presence of 0.34 to 0.50 per cent tannin (Aherne, 1974). In older feeders, Antoni (1964) suggested 1.0 to 1.5 kg. of faba beans per day or about 20 per cent of the ration. Huber (1972) agrees that calves older than 3 months of age produce good results with rations containing 20 per cent faba beans. Even a diet of cracked beans and hay has proven successful for growing steers with the addition of minerals and vitamins (Eden, 1968). When fed to cattle, the hulls of the beans should be cracked. Presber (1972) states "a 10 per cent share of uncracked whole beans in the diet will have a stimulating effect on the animals general digestion."

When feeding faba beans to dairy cattle, good results have been reported when the beans constituted 50 per cent of the concentrate (Eden, 1968; Huber, 1972). Other results (Antoni, 1964; Richter et al. 1964) report rations containing 30 per cent faba beans can be fed with no adverse effects on milk production or butterfat. In work by Ingalls and Mckirdy (1974), the addition of 17.5 or 35 per cent faba beans to the dairy concentrate appeared to have little effect on feed intake, milk production, milk protein content, or milk SNF if compared to rapeseed meal or soybean meal. They found a higher butterfat test with the 35 per cent faba bean ration. Presber (1972) cites Stahlin (1957) as reporting the quantity of milk produced and its fat content increased with the inclusion of beans in the ration.

Macleod, MacDearmid, and Kay (1972) found nitrogen retention by growing steers fed field beans similar to values obtained with

soybean meal and fish meal. In this study, nitrogen from field beans was less digestible than from either soybean meal or fish meal. There was no difference between digestion coefficients for diets with rolled barley and either whole or rolled beans, but when both barley and beans in the whole form were fed, dry matter and nitrogen digestibility coefficients were 10 per cent lower. In two of the digestion trials, dry matter intake was higher when steers were offered whole as opposed to rolled beans. Edwards, Duthie, Rogers, and Owen (1973) found bean hulls fed at 62 per cent of the concentrate mixture to sheep had digestion coefficients of 59.6, 58.2, 60.3 and 59.9 for dry matter, nitrogen, crude fibre, and energy, respectively. Metabolizable energy values of the bean hulls were calculated between 2.00 and 2.10 Mcal./kg.

Feeding Faba Beans to Swine

Faba beans appear to be a satisfactory protein supplement for fattening pigs. However, it is not recommended as the sole protein source. Faba beans and fish meal together produce good results (Antoni, 1964). The strong taste, derived from tannins, of faba beans causes young pigs to reject rations containing large amounts of the beans. In addition, high levels of faba beans in a ration can give stiffness and loss of weight (Antoni, 1964). It is generally agreed (Antoni, 1964; Eden, 1968; Huber, 1972) that faba beans give a darker color of meat and a more solid texture of bacon in swine carcasses.

Franck (undated) notes the inclusion of 15 to 20 per cent faba beans in a ration for fattening pigs will give satisfactory response. In work by Antoni (1964), rations containing faba beans at the levels of 10, 20, and 30 per cent for young, fattening, and finishing pigs, respectively, gave high average daily gains. At the 30 per cent level,

pigs were eating 0.97 kg. per day of the faba beans. In this study, faba beans showed no detrimental effects even in young pigs. Clarke (1970) found the replacement of soybean meal by faba beans in pig rations gave no significant differences in growth rate or feed conversion.

Feeding Faba Beans to Poultry

Some variation exists in the metabolizable energy value of faba beans when fed to chicks. Edwards and Duthie (1970) and Edwards and Duthie (1972) reported metabolizable energy values of 2.40 and 2.44 kcal per gram, respectively. Carpenter and Johnson (1968) found a value of 2.76 kcal per gram for faba beans. Clarke (1970) states that in determining the economic value of faba beans, a value of 2.82 kcal per gram of dry matter should be used.

Clarke (1970) found faba beans to have relatively high concentrations of linoleic acid and lysine and low concentrations of sulphur-containing amino acids and manganese. Linoleic acid is important to maintain egg size in poultry, and lysine would be important for swine rations since it is usually the first limiting amino acid in swine rations.

In work by Blair and Bolton (1968) as reported by Clarke (1970), liveweight gain, feed intake, and feed conversion of chickens were not affected by the inclusion of 10, 20, and 30 per cent faba beans in the diet. The diets were also supplemented with methionine. They also reported no adverse effects on growth or feathering when the diet contained 30 per cent faba beans. Bletner, Chalhoub, and Goff (1963) found abnormal feathering in chicks fed faba beans. The highest incidence of abnormal feathering was with chicks receiving 60 per cent faba beans supplemented with methionine and choline. Diets containing high levels of riboflavin, choline, niacin, and fat reduced feathering abnormalities.

Nitsan (1971) reported antinutritional factors in faba beans, with trypsin and chymotrypsin inhibiting activities at levels of about 1/60 to 1/30 of that found in raw soybean meal. Marquardt and Campbell (1973) reported that heat treatment (autoclaved 15 minutes at 121° C) of faba beans reduced the pancreas enlargement caused by raw faba beans, and improved feed utilization. The increase in pancreas size indicates the presence of trypsin, chymotrypsin or amylase inhibitors in raw faba beans. A significant response to heat treatment was obtained in growth rate when the ration contained 85 per cent faba beans, but there was little response when the ration contained less than 57 per cent faba beans. Most of the antinutritional factors in faba beans appeared to be in the dehulled bean, since heat treatment of the dehulled bean resulted in the responses noted above, whereas hulls did not affect pancreas size.

Both Marquardt and Campbell (1973) and Bletner et al. (1963) concluded that raw faba beans, when properly supplemented with methionine, will promote growth in young chicks at a rate similar to soybean meal as the protein supplement. Franck (undated) reported faba beans would give good response when fed to laying hens at 20 per cent of the diet.

Regulation of Feed Intake in Ruminants

Physical Regulation

Montgomery and Baumgardt (1965a) suggested that feed intake regulation was controlled by physical means with feeds of low nutritive value and by chemical or thermal mechanisms at higher nutritive values.

They supported the hypothesis that ruminants adjust food intake in relation to physiological demands for energy if fill or rumen load does not limit their consumption. At some undefined point, feed intake declines while the increased energy concentration of the ration allows maintenance of energy intake.

Dinius and Baumgardt (1970), working with sheep, found 2.47 kcal digestible energy per gram or a corresponding digestibility of 66 per cent to be the point between bulk limitation of intake and energy intake regulation. In dairy cows or heifers, feed intake was determined by the animals capacity or by the rate of passage of undigested materials of digestibility less than 66 per cent and by physiological mechanisms at higher digestibilities (Montgomery and Baumgardt, 1965b; Conrad, Pratt, and Hibbs, 1964). Conrad et al. (1964) concluded that at higher digestibilities, intake appeared dependent on metabolic size, production, and digestibility. Jones (1972) noted that factors that influence the rate of digesta passage from the reticulorumen control the intake of predominantly forage rations at least until digestibility reaches 55 - 66 per cent.

Physiological Regulation

Simkins, Suttie, and Baumgardt (1965a) theorized that satiation would be the point after feeding at which the concentration of certain blood metabolites increased and activated the satiety center in the hypothalamus. They found acetate and ketones to be the most probable signal compounds for a chemoreceptor since their utilization was increased after feeding and decreased upon starvation. Simkins, Suttie, and Baumgardt (1965b) found that a glucostatic mechanism for feed intake regulation was not important in ruminants. They also found that the infusion of

acetate and butyrate into cows resulted in a reduction of feed intake although this was not significant with butyrate. The infusion of propionate and butyrate significantly reduced voluntary consumption of long hay fed to cows. The decreased feed intake occurring with propionate infusion was associated with increased blood sugar concentrations, increased blood and rumen propionate and an increase in rumen pH. They suggested there could be chemoreceptors in the rumen wall, portal system or liver responding to increased propionate concentration. In addition, heat released during assimilation of infused propionate could be responsible for decreased feed intake via a thermostatic mechanism. The mechanism by which acetate causes a depression in feed intake was not known. When acetate was infused the decreased feed intake was associated with increased blood and rumen acetate concentrations.

In highly digestible rations, rumen volatile fatty acid absorption rates would be affected by rumen epithelia. The liver monitors the levels of amino acids, propionate, and ketone bodies provided by absorption from the forestomach and intestines. Blood metabolites such as blood glucose, acetate, ketone bodies, plasma nonesterfied fatty acids, and plasma amino acids would be adjusted according to requirements. High levels of plasma amino acids could cause reductions in feed intake.

Effects of Feeding Pelleted, Cubed, and Wafered Rations

Moore (1964) describes a pellet as finely ground forage compressed into a unit 1/4 to 3/4" in diameter and 1/4 to 1 1/2" in length, and having a bulk density of 40 to 45 lb/ft^3. The pellet can be made from forage or concentrate or both combined. Cubes are a highly compressed forage from long or coarsely chopped material and are usually 1" in diameter or square, and about 2" in length. Wafers are a highly

compressed forage made from long or coarsely chopped material. They are usually 2 to 3" in diameter, round or square, and 1 to 4" in length, with a bulk density of 30 lb/ft.^{3} Throughout literature available, there is some variation in terms used to describe units being fed.

Some of the advantages of pelleting are providing a balanced intake allowing no sorting of ingredients, easier handling and storage, decreased waste during handling and feeding, reduced dust, reduced labor involved, and easier adaptation to mechanical or self-feeding methods. A complete ration of cubes can help cut cost of milk production by reducing labor involved in handling baled hay and by bulk handling and automated feed systems (Summers, 1962).

Among the disadvantages of pelleting are the high cost of grinding and pelleting and the high cost of hauling bulky roughage to pelleting mills (Summers, 1962).

Factors Affecting Nutritive Value

There are several factors affecting the nutritive value of ground or pelleted forage. They are the physiological state of the animal, the fineness of grinding, the moisture content of the forage, the heat developed during pelleting, the hardness of the pellet, the orginal composition of the forage, the amount of readily available carbohydrate in the forage, the quality of the forage, and the amount of concentrate added to the pellet (Moore, 1964). Those physical factors which change the rate of passage of food through the gut, change the rate and nature of microbial fermentation, and cause variations of mechanical factors involved in prehending, masticating, and cudding of feed are as important as the chemical composition of the feed (Blaxter and McCGraham, 1956).

Physical Form of Roughage

Hay can be fed in several different physical forms. Some physical forms include long, coarsely chopped, ground, pelleted, cubed, and wafered. Each physical form produces changes in animal response, some of which may be desirable. The changes are reflected in certain performance characteristics such as feed consumption, weight gain, efficiency of feed utilization, and digestion of nutrients contained within the feed.

Chopping long or baled hay appears to have little consistent effect on animal response. Variations in experimental results of chopping would be due to a reduction in wastage and sorting rather than to any specific response. Changes in animal response from pelleting may be due to grinding, heating, application of pressure, or a combination of these treatments (Beardsley, 1964). Haenlein and Holdren (1965) compared the gross nutrient composition of hay from the windrow and after wafering and found only carotene content to be decreased by wafering. They suggested heat during the wafering process could have had an effect on chemical composition but it was not detected by proximate analysis.

Digestive Differences

Differences between ground or pelleted forage and long and chopped forage appear in the digestive tract of the animal. Pelleting allows for a more rapid prehension time with less mastication. With cubes, sheep require 10 to 15 minutes for consumption as compared to 50 minutes for consumption of the same forage chopped. It is apparent more muscular effort is expended in prehending, chewing, and cudding of chopped material than with cubes (Blaxter and McCGraham, 1956). The result is

less salivation with less secretion of buffer salts in the rumen. Therefore, because of the finer particle size, there will be less rumination and less stimulation of saliva secretion (Moore, 1964). In the reticulo-rumen, because the feed particle is finely divided and easily wetted, there becomes a more rapid solution of feed nutrients and a more rapid bacterial fermentation. The result is a more rapid production of organic acids or a faster rate of digestion. However, digestion is incomplete. Alwash and Thomas (1971) suspended cotton threads in the rumen and found the rate of disappearance of cotton threads was slower in ruminants fed ground and pelleted grass than those fed chopped grass. Higher levels of feeding resulted in decreased rate of disappearance of cotton threads. Since the completeness of digestion is dependent on the intensity of the digestive processes, the slow rate of disappearance of cotton threads indicated a severe depression of cellulolytic activity in the rumen with ground or pelleted grass.

Meyer, Gaskill, Stoewsand, and Weir (1959) conducted a test to determine digestive differences between chopped and pelleted hays with sheep. They killed sheep 0, 1 1/2, 4, and 8 hours after feeding of either chopped or pelleted forage and compared contents of the reticulo-rumen and other organs. They found a faster rate of passage of feed from the reticulo-rumen of sheep fed pelleted hay, rather than any difference further along the tract. They also found greater fatty acid production from rumen contents occurring at 1/2 to 4 hours after feeding of pelleted forage as compared to chopped forage, as well as greater CO_2 production. There was no change in methane production. Differences in volatile fatty acid production and CO_2 production were related to a greater number of microorganisms and finer particle size allowing more

surface for digestion. The nitrogen content was greater at all times in the rumen of sheep fed pellets.

Changes in pH and VFA Concentrations

When dairy cows were fed dehydrated alfalfa pellets as compared to alfalfa as the only feed, rumen pH was reduced from 6.9 to 6.0; pH was inversely proportional to the volatile fatty acid concentration (Moore, 1964). In vitro studies with rumen ingesta showed an increase in fatty acid concentration and CO_2 production for samples 1 1/2 and 4 hours after feeding pelleted hay (Meyer et al., 1959).

Meyer et al. (1959) postulated a more rapid rate of fermentation since they found a higher concentration of volatile fatty acids as well as a higher proportion of propionic acid to acetic acid in the rumen of ewes 1 1/2 to 4 hours after feeding ground or pelleted forage. The addition of concentrate further increased the difference.

Oltjen, Rumsey, and Putnam (1971) fed concentrate compared to pelleted forage to steers. They found ruminal acetate to propionate ratios of 1.2:1 for the all-concentrate ration and 4.3:1 for the pelleted forage ration. They found reduced acetate to propionate ratios gave increased gain and feed efficiency.

Alwash and Thomas (1971) found the mean concentration of short-chain fatty acids in the rumen increased with the level of feeding, and, at corresponding levels of feeding, was lower in animals given ground and pelleted grass as compared to chopped grass. These animals also showed a smaller percentage of acetic acid and a larger percentage of butyric acid. With both forms of grass, the percentage of propionic acid was greater at high levels of feeding that at low levels of feeding. With the increased volatile fatty acid concentration the resultant reduction in pH was intensified because of the smaller amounts of

buffer salts from saliva present.

The decreased pH may increase rate of absorption of organic acids from the rumen (Moore, 1964). Alwash and Thomas (1971) reported that at the high level of feeding, the mean pH was lower with animals on ground and pelleted grass than on chopped grass but that at the low level of feeding, there was little difference between treatments.

Visual examination of rumen contents showed a more fluid type of contents for pelleted hay than for chopped hay but no significant difference in moisture content. The difference in appearance was due to the fineness of the particles (Meyer et al., 1959). As the time after feeding lengthened the reticulo-rumen contents became more alike due to a greater amount of remastication of chopped hay. It could be postulated that grinding roughage before pelleting relieves sheep from remastication. Another factor is the faster rate of passage when ground hay is pelleted (Meyer et al., 1959).

Differences in Digestion Coefficients

It is generally agreed that increased rate of passage lowers the amount of digestion which can take place in the rumen, particularly of the cellulose and crude fibre fraction (Blaxter and McCGraham, 1956). Conrad and Hibbs (1973) found cellulose digestion dropped from 67.5 to 41.3 per cent when 3/4" alfalfa pellets replaced freshly cut chopped alfalfa. Heaney et al. (1963) compared the effects of pelleting forage at three levels of maturity. Results showed pelleting decreased the digestion of all constituents of the grass at all stages of maturity. The stage of maturity had no consistent effects on changes in digestion due to pelleting. Heaney et al. (1963) found the digestion of crude fibre depressed the most and crude protein the least; crude fibre digestion

was depressed an average of 16.3 per cent in pelleted forage.

Blaxter and McCGraham (1956) suggest that the more rapid passage of food through the digestive tract had relatively small effects on the digestibility of the constituents contained in the plant cells, but very marked effects on the digestibility of the fibrous components of the cell wall.

Alwash and Thomas (1971) found that at the same level of feeding, the digestibilities of organic matter, nitrogen, crude fibre and nitrogen-free extract were lower and the digestibility of ether extract was higher in the ground and pelleted grass than in the chopped grass. They found a positive relationship between the digestibility of organic matter in each form of grass and the mean retention time.

Feeding wafers to sheep, Haenlein and Holdren (1965) found digestibility of crude protein and crude fibre to decrease as particle size decreased. The digestibilities of nitrogen-free extract, dry matter, organic matter, gross energy, and ether extract were not significantly affected. The digestion of crude fibre was depressed the most which may mean that wafers made from high quality hay with a lower crude fibre content will suffer a relatively smaller digestion depression than wafers made from poor quality fibrous hay. Haenlein and Holdren (1965) and Blaxter and McCGraham (1956) concluded that the differences in intake level was the main factor for causing difference in digestibility. A lesser factor was the relationship of density and particle size on digestibility. Denser and smaller particle size resulted in lower digestibility of nutrients, especially crude fibre.

Water content of feces increased with increasing levels of intake. Higher water content of feces was related to lower digestion

coefficients of dry matter, organic matter, gross energy, and nitrogen-free extract. This suggests that higher levels of intake cause wetter feces giving less efficient nutrient utilization in the intestinal tract (Haenlein and Holdren, 1965).

Greenhalgh and Reid (1973) found a large reduction in dry matter digestibility with pellets, especially pellets containing all roughage. They reported that starch of barley would probably be completely digested and that this would tend to increase the dry matter digestibility coefficient.

Wilkins, Lonsdale, Tetlow and Forrest (1972) found the digestion of organic matter and cellulose decreased with decrease in modulus of fineness associated with more rapid passage of finely milled material through the alimentary tract. Organic matter digestibility increased with decreasing modulus of fineness. Dustiness restricted the intake of some of the feeds.

Johnson, Ricketts, Klosterman, and Moxon (1964) found digestion of ground or pelleted hay lower than unchopped forage for steers. The finely ground or pelleted hay passed through the digestive tract of ruminants faster than the same hay when fed in the long or coarsely chopped form. To determine if grinding and pelleting processes prior to feeding had actually physiologically or chemically affected total digestibility of the cellulose tissue in hay, cellulose digestion by rumen microorganisms was determined by in vitro techniques. Ground hay appeared to have a lower digestibility. This was explained by a low apparent digestion coefficient for ground hay in vitro.

Rate of Passage

Normally ruminants eat to rumen fill resulting in rumen fill being the limiting factor in feed intake. If animals were fed free

choice ground or pelleted forage, there was a reduction in retention time resulting in increased consumption of feed per unit time. Retention time usually decreased as intake increased in hand fed ruminants. Decreasing retention time usually increased intake because the increased rate of passage of ground and pelleted forage from the rumen makes more space available for more feed which in turn results in a greater consumption of feed dry matter (Moore, 1964; Johnson et al., 1964; Beardsley, 1964; Blaxter and McCGraham, 1956; Greehalgh and Reid, 1973).

The fill in the rumen for coarse forages may be relatively constant 24 hours after feeding. The rumen fill for ground or pelleted hay 24 hours after feeding was less than for the long hay. Chopped hay had a greater retention time than the pelleted hay. The level of consumption of pelleted hay had no effect on retention time (Johnson et al., 1964).

Therefore, the amount of rumen fill and the rate of passage from the rumen operate together in making more room available for more feed (Moore, 1964). Johnson et al. (1964) concluded that when hay constituted a major portion of the diet, grinding and pelleting increased voluntary food consumption but simultaneously decreased digestion of the hay. The decrease in digestion was due to an increase in rate of passage since the cellulose in the long and pelleted form was equally digested in vitro by rumen bacteria.

Energy Retention

Although total digestible nutrients, digestible energy, and metabolizable energy values for pelleted forage are reduced due to pelleting, net energy values remain the same when fed on an equal intake basis (Moore, 1964). Wainman, Blaxter and Smith (1972), feeding pelleted

grass to sheep, found an increase in voluntary intake of dry matter by 27 per cent and intake above maintenance to increase by 59 per cent. The percentage of gross energy supplied above maintenance which was retained was 28 per cent greater for pellets than for long grass. They concluded that energy retention in sheep almost doubled when grass was pelleted.

Blaxter and McC Graham (1956) found grinding and pelleting increased fecal energy loss but this loss was compensated by lower losses of energy as heat and methane with no significant effect on net energy. Meyer et al. (1959) showed no change in methane production. The lowered bacterial fermentation was associated with a lower proportional production of acetic acid and a higher proportional production of propionic acid (Moore, 1964).

Pelleting High Quality Rations

As quality of long or chopped forage is increased, or as quality of total ration is increased by addition of concentrates to the forage ration, there is a greater proportion of propionic acid produced. There is also a reduction in feed intake and gain and an increase in feed efficiency. The change could be related to a larger reduction of the acetate:propionate ratio and to a larger production of other acids such as lactic acid (Moore, 1964).

Moore (1964) reported that the poorer the quality of forage, the greater the difference pelleting makes, or that the better the forage quality the less the difference pelleting makes. This argument is strengthened by the fact that when concentrates are fed along with forage so that rapid rate of gain results, pelleting the ration has less effect on acceptability.

Greenhalgh and Reid (1973) working with sheep found pelleting

increased intake by 19 per cent for better quality grass but by 44 per cent for poor grass. They noticed that sheep responded much more to the pelleting of their diet than did cattle, increases being 45 and 11 per cent respectively. The interaction was mainly due to a low intake of long roughage by sheep.

Beardsley (1964) compared ground and pelleted forage to long or chopped forage fed to calves and found daily feed intake increased by 25 per cent, daily gain increased by 98 per cent and feed per unit gain decreased by 36 per cent. When similar rations were fed to large steers, improvements in intake, gain, and feed efficiency of 16, 21, and 4 per cent respectively, were obtained from pelleting. In lambs, similar significant improvements were noted.

The overall response of pelleting a high roughage ration already ground is small. Pelleting a ration low in forage usually has an adverse effect on intake and gain (Beardsley, 1964). McCrosky, Pope, Stephens, and Waller (1961) fed Hereford steers rations of 1:4 and 4:1 concentrate:roughage ratios in the pelleted form. They found rate of gain and feed intake significantly higher on the pelleted 1:4 ration. Pelleting the 4:1 ration gave no significant change in rate of gain but decreased feed intake slightly. Pelleting improved feed efficiency.

Minson (1963) found that as gain approached a maximum, indicating a high quality ration, there was little advantage to pelleting in terms of consumption or gain. Johnson et al. (1964) concluded that when roughages were fed with high portions of concentrate, the physical form of the roughage had much less effect on digestion and performance than when the roughages were fed alone.

Pelleting Complete Rations

When pelleting complete rations the advantage depends on the ratio of roughage to concentrate. Feed intake and gain will be reduced when a ration containing more than 80 per cent concentrate is pelleted. However, feed efficiency will be improved slightly. Feed intake was increased 10 per cent, gain increased 23 per cent and feed efficiency increased 10 per cent when a pelleted ration contained only 20 per cent concentrate and 80 per cent roughage (Summers, 1962). Feed consumption was increased an average of 30 per cent by pelleting all-roughage rations. However, there was a reduction of 5 per cent in consumption if the ration had less than 20 per cent roughage.

Gain stimulation follows a pattern similar to consumption. Increased gains obtained from a high roughage pelleted ration were the result of increased feed consumption. This was especially true when pelleting lower quality roughages. Average daily gains can be increased 50 per cent by pelleting all roughage rations and can be reduced 4 per cent in rations of less than 20 per cent roughage (Summers, 1962).

Feed efficiency is also affected by the roughage:concentrate ratio but in the reverse order as intake and average daily gain were affected. There was a small increase in feed efficiency in low roughage rations. Feed efficiency can be increased 40 per cent by pelleting all roughage rations but by only 4 per cent by pelleting rations with less than 20 per cent roughage. The 45 to 50 per cent roughage level in pelleted rations was the level at which reduction began in average daily gain and feed consumption (Summers, 1962; Conrad and Hibbs, 1973; Klopfenstein and Schneider, 1973).

Tayler (1970) found a maximum efficiency of feed conversion

when the supplement was comprised of 40 per cent dried grass or 50 per cent barley when feeding silage to steers. He stated the effects of feeding barley in wafers were relatively small. The inclusion of 58 per cent barley in wafers increased rate of empty body weight gain by only 8 per cent compared with a response to milling alone of 5 per cent. He concluded that the advantage of the inclusion of barley in wafers would lie more in the effect of the cost of feed than in nutrition.

Increased Intake by Pelleting

Increased intake is a major factor in improved performance observed when long or chopped roughages are ground or pelleted (Beardsley, 1964). Meyer et al. (1959) fed chopped alfalfa to lambs ad libitum and fed pellets to another group of lambs such that level of intake was the same; gains were almost identical. When the pellets were fed ad libitum, intake was increased 31 per cent and gain 48 per cent. Oltjen et al. (1971) fed finishing beef cattle to compare an all concentrate ration to an all forage pelleted ration. Best gains and feed efficiency were from the all concentrate ration but groups fed partial concentrates and forage and all forage rations were not different in gains and did not show a poor feed efficiency. Good performance of these rations was due to pelleting, permitting animals to consume sufficient feed to permit reasonable gain. The use of long hay would have limited feed intake too much. In this experiment, fine grinding of the forage was the major factor causing increased feed consumption. The response to pelleting was usually most effective in increasing the performance of ruminants when hay constituted most of the ration. Increasing voluntary feed intake had the effect of increasing efficiency of utilization of the ration for productive purposes because the cost of maintenance was spread over a

greater number of units of feed consumed (Moore, 1964).

Aughtry (1971) in evaluating the physical form of alfalfa reported that the product must be ground coarse enough to retain the "roughage factor." There is a significant interaction between fibre level, source of fibre, and physical condition as it relates to particle size distribution. The fineness of grind of alfalfa exerts an appreciable effect on the feedlot performance of rations tested.

Meyer et al. (1959b) tested finely ground vs. ground and pelleted vs. ground mixed with water vs. reground pelleted mixed with water. They found that pelleting or adding water to finely ground hay increased feed consumption and daily gain. Feed consumption did not increase as markedly when coarse material was pelleted as when fine material was pelleted. Much of the influence of pelleting was obtained by wetting the ground hay. They concluded that grinding causes the increased feed consumption.

Haenlein and Holdren (1965) found sheep preferred wafers over fines from wafers. This statement was explained partly by a higher fibre and lower protein content of the fines. The dusty condition of the fines may have reduced preference.

Tetlow and Wilkins (1972) feeding wafers to lambs, found the dusty nature of wafers of low density was a major factor reducing intake. They also found a relatively low intake of wafers early in the experiment reflecting the difficulty the sheep initially had in prehending the feed. Haenlein and Holdren (1965) observed sheep handled the wafers easily except for highly dense wafers. There were no undesirable effects such as bloating, choking, scouring or foundering on ad libitum consumption of wafers.

Wallace, Raleigh, and Sawyer (1961) fed calves either 4" wafers, 3/8" pellets, or chopped hay. They found hay consumption and rate of gain significantly increased while hay refusals significantly decreased as a result of pelleting. Apparent digestion of nutrients was not significantly different between treatments. They reported that dust was reduced by pelleting the hay.

Milk Production by Cows Fed Pellets, Cubes, or Wafers

Pellets

Minson (1963) states that any improvement in the production value of a ration by pelleting could be caused by (a) an increase in dry matter digestibility and net energy values of the feed, (b) an increase in feed consumption, or (c) a combination of both. He also reported that wafers, because they are made from coarsely chopped hay and not ground hay, will not show similar advantages as pelleted rations.

Ronning, Meyer, and Clark (1959) and Keith, Hardison, Huber and Gref (1961) found cows on pelleted hay consumed more dry matter and produced more milk than those receiving chopped hay. Ronning et al. (1959), feeding the chopped hay ration with concentrates such that concentrates amounted to 12 per cent of the dry matter intake, found dry matter intake and milk production similar to that of the pelleted hay ration. Butterfat percentage was unaffected. Moody (1962), comparing alfalfa hay, alfalfa pellets, and Coastal Bermuda grass pellets found no significant difference in daily intake or milk production, but found milk fat percentage significantly higher for the alfalfa hay and SNF percentage significantly lower for Bermuda grass pellets.

Porter, Johnson, Eaton, Elliot, and Moore (1953) and Bishop et al. (1963) found actual milk production greater and percentage fat

lower with pellets. In a second experiment by Porter et al. (1953), pellets caused a reduction in intake due to the alfalfa being more finely ground, and therefore, compressed into a harder pellet. These pellets gave a decreased milk fat percentage and resultant decrease in fat-corrected milk.

Tigges, and Ward (1959) fed a 3/8" pelleted concentrate and found milk production, fat test, and 4 per cent fat-corrected milk not significantly different. Waldern and Cedeno (1970) found more milk, protein, SNF, fat, and fat-corrected milk from pelleted concentrate rations than with meal form rations. Percentage fat was lower with cows fed pelleted rations. They reasoned that the increase in actual and 4 per cent fat-corrected milk production was due to pelleting associated with changes in rumen metabolites, and greater efficiency in energy utilization for milk production by cows on pelleted rations. They found an increase in molar per cent rumen acetate and a decrease in butyrate, with little changes in propionate or valerate in rumen contents of cows fed pelleted concentrate rations. Bishop, Loosli, Trimberger, and Turk (1963) found molar per cent of acetic greater and butyric lower from high roughage rations. The proportion of rumen propionic acid was not altered.

Bishop et al. (1963) fed pelleted roughage, varying the ratio of loose concentrate to pelleted roughage. The efficiency of utilization of total digestible nutrients for production of fat-corrected milk was in favor of pellets. When a ration with a low ratio of roughage to concentrate was fed (5 lb. roughage and ad lib. concentrate), there was a slight increase in milk protein and a significant decrease in milk fat percentage as compared to a high roughage-low concentrate ration

(ad lib. roughage plus 1 lb. concentrate/4 lb. milk produced). There was no effect on SNF. Total digestible nutrients consumed were 30 per cent greater with the high concentrate ration.

Ronning (1960), feeding varied concentrate levels (0, 15, 30 and 45 per cent of the ration) in a finely ground alfalfa pellet, found milk production increased as concentrate intake increased to 30 per cent of the ration, but increasing the concentrate to 45 per cent of the ration resulted in a decrease in milk production. Butterfat production decreased for 30 and 45 per cent concentrate levels as compared to the 15 per cent concentrate level. Four per cent fat-corrected milk was uniform between treatments showing that increased energy intakes, associated with higher levels of concentrate feeding, were not reflected in increased energy output as 4 per cent fat-corrected milk, due to lower fat production. He suggested that milk production levels were not affected by feeding of pellets.

Brooks, Miller, Beaty, and Clifton (1962) compared feeding long hay and pelleted hay plus 2 lb. of long hay per day. They found that cows fed pellets plus 2 lb. of long hay per day produced more milk and more fat-corrected milk per day than did those fed the long hay. The difference was due to an increase in intake. In this study, concentrates were fed according to production. Milk from cows fed pellets plus hay contained significantly more fat, SNF, and protein than milk from cows fed long hay. The addition of 2 lb. of long hay alleviated the reduction in milk fat content and prevented rumen parakeratosis. Cows fed the long hay had a lower plane of nutrition, which explains why SNF and protein were that much higher in the milk from cows fed the ration of pellets plus hay. They suggested that changing the physical

forms of feed may increase SNF and protein because of the effect on rumen fermentation.

Conrad and Hibbs (1973) fed pellets (1" long and 3/4" in diameter) to lactating cows in comparison with freshly cut chopped alfalfa and with corn silage and alfalfa hay rations. They found the pellets to be highly acceptable to cows providing 3 to 5 lb. of long hay was included in the daily ration. Between rations, there was no change in milk production but there was a slight decrease in butterfat with the pellets. Butterfat decline was due to much of the forage in the 3/4" pellet being too fine for complete cellulose digestion before passing from the rumen. Cellulose digestion dropped from 67.5 to 41.3 per cent with the pellets. An increase in daily feed intake compensated for some of the reduction in cellulose digestibility.

Wafers

Veltman, Thomas, and Molitorisz (1962) compared alfalfa wafers with hay when fed to lactating cows. Daily dry matter consumption of high quality alfalfa was similar for treatments, but with average or poor quality hay, wafers resulted in less dry matter consumption than long hay. Milk production and milk fat tests were slightly more for cows fed the average and poor quality hay. They reported handling losses were increased with wafers of low quality hay and were least for wafers of high quality hay. Increased handling losses could be due to increased hardness of wafers made from low quality hay.

Ross, Fourt, and Gephart (1959) fed Jersey cows wafers 4" in diameter and 1" thick. No supplemental feeds were used. The mean daily 4 per cent fat-corrected milk was 19.9 lb. for both groups. Butterfat was significantly lower. Cows fed baled hay gave milk of 5.74 per cent

butterfat as compared to 5.48 per cent for milk from cows fed wafers, a decrease of 0.26 per cent. Cows fed wafers ate 27.7 lb. per day and gained 0.74 lb. per day while cows fed baled hay ate 22.0 lb. and lost 1.04 lb. per day. The differences were significant. They noticed less wastage in the bunk with wafers.

Ronning and Dobie (1962) fed wafers of two sizes, 1 1/2" and 5/8" square. Consumption of wafers was equal. Daily consumption of wafers averaged 5.2 lb. per cow more than consumption of baled hay hand fed. If both were fed ad libitum, intake of wafers averaged 6.7 lb. per cow daily more than consumption of baled hay. There was an average of 1.8 lb. more 4 per cent fat-corrected milk daily per cow on wafers than on baled hay. There was no significant effect on milk fat or SNF.

Hutton, Ronning, and Dobie (1964) working with wafers 2" by 2 1/2" found daily consumption of wafers to be 3.5 lb. per cow more than baled hay. They found aerated wafers gave a 2.0 lb. per day increase in fat-corrected milk. There was no significant effect on milk fat or daily liveweight gain. It was noticed that refused hay samples by cows were lower in protein and higher in crude fibre content than offered hay. Cows also tended to select wafers over fines when both were available.

Bringe, Niedermeier, Larsen, and Bruhn (1958) fed pellets (4" diameter) to lactating dairy cows who were past the peak of their lactation curve. When concentrates were fed at 1 lb. per 3.2 lb. 4 per cent fat-corrected milk, pelleted hay resulted in increased intake and gave increased 4 per cent fat-corrected milk. Concentrates fed at 1 lb. per 4.2 lb. 4 per cent fat-corrected milk resulted in no change in intake or milk production. Bringe et al. (1958) reported cows ate pelleted hay without difficulty or apparent ill effects.

Cubes

Feedstuffs (1973) reported complete cubed rations decreased butterfat of milk by as much as 20 per cent when cubing baled hay. They reported a 17 per cent reduction when cubes were made from field chopped hay. Cows eating baled hay gave milk of 4.2 per cent butterfat while cubes of field chopped hay and cubes of baled hay resulted in milk of 3.5 and 3.4 per cent butterfat, respectively. They concluded cubes to lack sufficient coarse forage to maintain the proper fermentation process for desired fat levels.

In a study of cubed complete rations by Murdock (1972), results showed a depression in milk fat tests with cubed rations. This milk fat depression appeared to be more pronounced in mature cows than in first calf heifers. In a 4-week period on the cubed ration, milk production increased but milk fat decreased, giving a decrease in 4 per cent fat-corrected milk. Murdock (1973) found fat depression greatest during the period of maximum milk production for 4 to 8 weeks post-partum.

Murdock (1972) found body weight recovery following parturition to be more rapid in cows fed the cubed complete ration. This fact, plus the low milk fat tests, suggested possible alterations in the normal volatile fatty acid production in the rumen. Rumen fluid analysis showed a shift toward a lower acetic to propionic acid ratio when the complete cube was fed. This response was associated with the physical state of the roughage, ie. fineness of grind of the alfalfa. Due to the reduction in fat test being more pronounced at higher production levels when cubed rations with 55 or 40 per cent concentrate were fed, it was believed there could be an interaction between physical state, roughage to concentrate ratio and level of feeding (Murdock, 1972; 1973).

In addition, Murdock (1972) had cows refusing cubed complete rations just before or after parturition. Pathological and histological examination showed slight hyperparakeratosis and thickening of the rumen villi, subacute ulcerative abomastitis and some thickening of the mucosa of the upper intestinal tract in some of the cows fed cubes. Vidacs and Ward (1960) suggested the low acetate to propionate ratio associated with cubed rations may be the causative agent and that destruction of papillae may result in alterations of volatile fatty acid absorption.

Fossland and Fitch (1958) fed a complete pelleted ration and found no significant change in milk production or body weight. They reported that complete pelleted rations gave poor rumination, chronic bloat, decreased reproductive efficiency and depraved appetite.

Theories on Milk Fat Depression

Reduction of Acetic Acid

Several theories have been postulated to explain why feeding high levels of concentrate in the pelleted form decrease milk fat. Van Soest (1963) reviewed these theories. The first theory is a deficiency of rumen acetic acid. Decreases in acetic acid with pelleted rations have been observed by most researchers (Thomas, Bartley, Pfost and Meyer, 1968; Jorgensen and Schultz, 1963; Jorgensen, Schultz and Barr, 1965; Van Soest, 1963; Schmidt and Van Vleck, 1974). Associated with reductions in rumen acetic acid have been increases in rumen propionic and valeric acids (Jorgensen *et al.*, 1965; Thomas *et al.*, 1968; Jorgensen and Schultz, 1963). Van Soest (1963) suggested that an acetate deficiency does not really exist since the decline in rumen proportions of acetate could be the result of an increased production of propionic

acid. Blood studies show no important drop in blood acetic acid associated with low milk fat (Van Soest, 1963). Jorgensen and Schultz (1963) found rumen acetate to decrease but there was still a sufficient supply of acetate unless rumen volume was reduced.

Jorgensen et al. (1965) associated a marked depression in milk fat with a narrow acetate:propionate ratio. They also found a significant increase in the percentage of rumen valeric acid and a decrease in isobutyric and isovaleric acids. Jorgensen and Schultz (1963) found acetate: propionate ratio to be the most consistent change associated with milk fat depression.

Jorgensen et al. (1965) found decreased concentrations of blood ketone bodies associated with the depression of milk fat. The depression in blood ketone bodies was thought due to higher levels of glucogenic propionic and valeric acid, with lower levels of butyric acid. Van Soest (1963) noted that when propionate was fed, there was a depression in milk fat and a marked antiketogenic activity.

Reduction of B-hydroxybutyric Acid

The second theory is that there is a reduction in the amount of B-hydroxybutyric acid in the blood and, consequently, a deficiency in the amount of this four-carbon unit which is available for milk fat synthesis. B-hydroxybutyric acid is an essential precursor of the short chain fatty acids in milk fat (Van Soest, 1963). The usual pathway of butyrate metabolism involves conversion to acetoacetyl Co A which in turn can form acetyl Co A or ketone bodies. Ketone bodies are utilized by the mammary gland in the secretion of milk fat. Van Soest (1963) cites Shaw (1955) as indicating B-hydroxybutyrate to be utilized 2.5 times more efficiently than acetate for milk fat synthesis.

Jorgensen et al. (1965) found high correlations between milk fat percentage and the glucogenic metabolites. Negative correlations between milk fat percentage and rumen valeric and propionic acid, and blood glucose suggested their importance in reducing milk fat. They explained the mode of action of glucogenic metabolites could have a depressing effect on the potential lipogenic metabolites. This was suggested by a high negative correlation between propionic acid and acetic acid, butyric acid and ketone bodies. They concluded that the major factors depressing milk fat involved a high level of glucogenic metabolites that reduced blood ketone and lipid levels and stimulated a fattening type of metablolism at the expense of milk fat synthesis.

Endocrinological Control of Fat Mobilization

A third theory of low milk fat involves the endocrinological control of fat mobilization. The theory states that "the high propionate production causes a glucogenic response in the body that suppresses the mobilization of fat from the tissue and thereby causes a decline in the blood lipids that are available for milk fat synthesis." Also, fatty acid esterification in adipose tissue is elevated which decreases the availability of triglycerides in the mammery gland (Van Soest, 1963; Schmidt and Van Vleck, 1974).

There are other indications that fat metabolism is involved in the adaptation of the animal body to non-specific stress. Fasting and underfeeding tend to produce a high ratio of acetate to propionate in the rumen, with a short term result of increased milk fat concentrations. However, there is a readjustment to underfeeding requiring between 2 to 4 weeks which decreases fat and SNF in milk produced. The readjustment is a change to a more economical utilization of energy. Body fat in part serves as the maintenance source of energy while adjustment takes

place.

When the fat mobilization factor is suppressed under conditions of low milk fat, the efficiency of utilization of acetate and propionate for fattening are increased. Body fat synthesis is promoted by an excess of reduced enzymes. The metabolism of propionate, glucose, and other glucogenic substances would produce an excess of reduced enzymes. These reactions would suppress fat mobilization in the tissues and deprive the udder of essential materials for fat synthesis, but promote fat synthesis in the tissues. It should be noted that hydrogen transport mechanisms control rumen acid ratios and carbohydrate and fat metabolism in the ruminant. The fatty acid composition of milk fat from cows fed restricted roughage diets is depressed in the proportion of short chain fatty acids. The feeding of unsaturated oils, fasting or underfeeding or heat stress produce similar changes. These changes occur with the feeding of finely ground pelleted roughage to dairy cows. Pelleted forage has caused increased unsaturation of body depot fat (Van Soest, 1963). Saturated fats tend to increase milk fat whereas unsaturated oils cause a marked depression. The mode by which unsaturated oils lower milk fat is a function of their role as hydrogen acceptors in the rumen and possibly in the body of the ruminant as well.

Van Soest (1963) reasoned that if the metabolic processes that produced low milk fat and ketones were regarded as opposite extremes and the role of acetate was regarded as a function of the ratio with propionate, a concept might be developed. This concept would suggest that fat mobilization would be associated with lower efficiency of feed utilization for fattening and high concentrate and ground roughage would be associated with low milk fat and high feed efficiency for fattening. Condi-

tions which tend to lower milk fat cause an increase in the efficiency of fattening in non-lactating animals, and conditions which tend to increase milk fat are associated with a decrease in the efficiency of fattening of these animals.

This theory is consistent with high producing dairy cattle losing body weight after parturition; body tissues are utilized and lost in the form of milk. Thus, the efficiency of milk production is high under such conditions.

Methods of Maintaining Milk Fat

Milk fat depression can be reduced in a number of ways. Thomas et al. (1968) reported that there appeared to be a minimum particle size which under a given set of conditions will not alter milk fat content or rumen volatile fatty acid concentrations. The degree of particle size reduction of ground hay has more influence on fat content of milk and ratio of rumen volatile fatty acids than heating or pelleting treatments. The feeding of pelleted concentrates depressed milk fat content, but the extent to which fat content was depressed depended on the quantity of concentrate and roughage fed.

Palmquist, Smith, and Ronning (1964) found that when concentrates and hay pellets were fed at separate times, there was less reduction in percentage fat. When hay pellets were fed 4 hours after the concentrate feeding and as the grain supply declined in the rumen, the pellets could have supplied precursors for fat synthesis. This could have prolonged the period of optimum precursor supply for fat synthesis resulting in a more normal milk fat concentration.

Schmidt and Van Vleck (1974) suggested possible guidelines to prevent milk fat depression as being:

(1) feed unground forage at a minimum rate of 1.5 lbs. of hay per 100 lb. body weight daily.

(2) feed a ration containing at least 17% crude fibre.

(3) if using ground forage use a screen greater than 1/8" in diameter.

(4) feed forages and concentrates separately.

EXPERIMENTS AT THE UNIVERSITY OF ALBERTA

Introduction

An experiment was designed to study the effects of feeding a complete cubed ration to lactating dairy cows, and to study the effects of replacing rapeseed meal by Vicia faba beans (faba beans) of the Dainea variety as the protein supplement. Studies on feed intake and milk production were carried out. Digestion trials were carried out to determine digestibility of dry matter, energy, and protein.

A second experiment was designed to study the acceptability of faba beans as a protein supplement for growing Holstein bulls and heifers. Studies on growth rate and feed consumption were carried out over a period of 58 to 65 days.

Experimental

Experiment 1

Design

The experiment was designed as a two-way analysis of variance having three physical forms of the ration and two sources of protein, for a total of six treatments as follows:

Chopped hay + concentrate	rapeseed meal
	faba beans
Complete cube + chopped hay + concentrate	rapeseed meal
	faba beans
Complete cube	rapeseed meal
	faba beans

Twenty-four Holstein cows from the University of Alberta dairy herd were allotted to the six treatments (4 cows per treatment) on the basis of age and expected level of milk production.

Experimental Rations

Two concentrate mixtures were formulated (Table 1), to be fed with roughage at a constant ratio of 60 per cent roughage and 40 per cent concentrate. It was calculated that the total ration would contain 14 per cent crude protein and a calcium:phosphorus ratio of 2:1. In the concentrate mixture containing rapeseed meal, the rapeseed meal, minerals, and vitamins were pelleted and mixed with rolled barley to reduce sorting of the feed. In the mixture containing faba beans, an amount of faba beans, equivalent to the rapeseed meal in the previous mixture, was incorporated into a similar pellet. This was mixed with the remainder of the rolled faba beans and barley.

Cubes of similar composition (60 per cent roughage and 40 per cent concentrate) were prepared at Mayerthorpe, Alberta.[1] They were prepared in a 3/4" die and were 1 1/2 to 2" in length. The hay was coarsely chopped before entering the die.

In the treatment of cubes plus concentrate and chopped hay, chopped hay was fed at 0.5 per cent liveweight and the meal added to maintain the proportions of 60 per cent roughage and 40 per cent concentrate. This treatment was included to determine whether a constant small amount of coarse roughage would prevent butterfat depression in milk that might be caused by a completely cubed ration.

Near the end of the experiment, a supply of cubes prepared from Alfalfa hay only were obtained and fed to a few cows at varying stages of lactation.

---

[1]Paddle Valley Products Ltd., Box 508, Mayerthorpe

Table 1

Concentrate Mixtures

Ingredient	(1)	(2)
Barley	89.4	77.5
Rapeseed Meal	8.6	-
Faba Beans[1]	-	20.5
Limestone	0.7	0.5
Calcium Phosphate	0.3	0.5
Co-I Salt	0.5	0.5
Vitamin Mix*	0.5	0.5
Total	100.0%	100.0%

Analysis (Dry Matter Basis)	CP (%)	G.E. (Mcal/kg.)
Rapeseed Meal Concentrate	16.1	4.46
Faba Bean Concentrate	16.8	4.49
Rapeseed Meal Cubes	17.8	4.57
Faba Bean Cubes	16.8	4.61
Hay	12.7	4.63

* formulated to supply 5000 I.U. of vit. A, 6300 I.U. of vit. D, and 5 I.U. of vit. E per Kg. of feed

[1] Appendix Table D for analysis

Animal Management

Two weeks prior to parturition, cows were offered their designated experimental ration according to calculated maintenance requirements for digestible energy (NRC, 1971), to provide a period of adjustment to the ration. After calving, the daily allotment of feed was increased according to the cow's voluntary appetite and digestible energy requirements for maintenance and milk production.

Some cows rejected the cubed ration and went off-feed, resulting in a ketotic condition. Treatment with propylene glycol and a change to chopped hay and meal in place of cubes, corrected the condition. Chopped hay and meal were fed to these cows until feed intake was approximately normal again.

The cows were tied in individual stalls in the Dairy Cattle Research Unit, and were allowed exercise in the afternoons in the outside corrals. Fresh water and a mixture of 50 per cent trace mineral salt and 50 per cent calcium phosphate were available free-choice.

The rations were fed in equal portions twice daily at 8:00 A.M. and 5:00 P.M. All feed offered and unconsumed was weighed and recorded daily.

Digestion Studies

Digestion studies were conducted on 24 cows, 4 cows from each treatment combination. During the digestion study, feed offered was reduced slightly to reduce weigh-back of unconsumed feed over the four-day collection period of feces.

The fecal collection apparatus used was based on collection bags and urine deflectors similar to those developed by Balch et al. (1951). Urine was not collected. Total feces collected was weighed and recorded twice daily at 6 A.M. and 3 P.M. daily. Two per cent was retained and frozen from each collection. At the end of the trial, the samples from each cow were combined and dried at 70°C for 72 hours in a forced-draught Despatch oven. The samples were then allowed to equilibrate with the atmosphere, weighed and subsequently ground in a Waring blender. Samples were stored for later analysis.

Samples of the experimental rations were collected daily dur-

ing the digestion trials, composited, ground through a 20 mesh screen in a Wiley laboratory mill and retained for later analysis.

Milk Samples

Milk production was recorded daily and samples of milk for analysis of fat, solids-not-fat, and protein were collected every third week. Milk samples were collected at afternoon and morning milkings in portions similar to milk production. Cows were milked at 6A.M. and 3 P.M. daily.

Analytical Methods

Dry matter and crude protein were determined on feed and fecal samples by AOAC (1965) methods. Gross energy of feed and fecal samples was determined by combustion at 24 atmospheres of oxygen in a Parr oxygen bomb calorimeter.

Milk samples were analyzed for percentage fat with a Milkotester,[1] protein by AOAC (1965) methods, and solids-not-fat (SNF) by the bead test (Golding, 1964).

Statistical Analysis

Data were analyzed using the ANOVA2 and AOV5 analysis of variance programs of the University of Alberta Computing Center (Smillie, 1969). Duncan's New Multiple Range Test (Steel and Torrie, 1960) was used to compare differences between means. Appendix Table A shows mean squares.

---

[1]A/SN Foss Electric, Hillerød, Denmark.

Experiment 2

Experimental Rations

The treatments (Table 2) were formulated to test the acceptability of feed and seed grade faba beans as a protein supplement for growing bulls and heifers. All experimental animals were offered 1 kg. of chopped hay daily in addition to the concentrate ration.

Table 2

Ration Formulation

Ration Ingredient (Kg. or %)	1	2	3	4	5
Rolled barley	100	80	80	60	60
Seed grade faba beans	-	20	-	40	-
Feed grade faba beans	-	-	20	-	40
Analysis (Dry Matter Basis)					
CP (%) (Actual)	13.0	15.9	15.9	18.8	18.8
DE (Mcal/Kg.) (Calculated)	3.26	3.07	3.07	2.89	2.89

Animals and Management

Twenty dairy animals, 10 bulls and 10 heifers, averaging 250 kg. liveweight were started on trial at the Edmonton Research Station, University of Alberta. Animal weights ranged from 143 to 339 kg. The animals were first divided into sex and then assigned to one of the five experimental treatments, balanced for weight as closely as possible.

Animals were housed in the Dairy Cattle Research Unit, and were tied in individual stalls over slatted floors. Fresh water and a mixture of 25 per cent limestone, 25 per cent calcium phosphate, and 50 per cent trace mineral salt were available free choice.

The bulls and heifers were offered the experimental rations and were brought up to full feed of concentrate over a period of 7 days. All feed and unconsumed feed was weighed and recorded once daily.

All animals were weighed at the beginning and end of the trial, using an average of the weights taken on two consecutive mornings before feeding and after water had been withheld for 14 hours. Bulls and heifers were on the experimental rations for periods of 65 and 58 days, respectively.

Statistical Analysis

An analysis of variance was computed using the University of Alberta Computing Center program C.S. 2384 (ANOFPR) written by Weingardt (1973). Appendix Table B shows mean squares.

RESULTS AND DISCUSSION

Rapeseed Meal Versus Faba Beans as a Protein Supplement

The rapeseed meal and faba bean supplements were each fed in the chopped hay and concentrate rations (without any cubes) to four cows. There were no significant differences between protein sources as measured by milk production per day, 4 per cent fat-corrected milk (FCM), per cent SNF, or per cent protein for the first 6 to 16 weeks of lactation (Table 3). There was a 17.0 per cent increase ($P < 0.05$) in per cent fat when the faba bean ration was compared to the rapeseed meal in the first 6 weeks of lactation (Table 3). The 9.2 per cent decrease in milk production per day with the faba bean ration in the first 6 week period accounts for the equal production of 4 per cent FCM daily. For the first 16 weeks of lactation, there was a 16.8 per cent increase ($P > 0.05$) in per cent fat when the faba bean ration was compared to the rapeseed meal ration.

The reason for the higher butterfat test for the faba bean ration is not apparent since calculated crude fibre levels were lower with the faba bean concentrate; 6.33 as compared to 6.50 per cent for the rapeseed meal concentrate. Faba beans have a crude fibre level of 8.7 per cent (laboratory analysis) as compared to 14.9 per cent for the rapeseed meal (Crampton and Harris, 1969). The higher fat percentages cannot be explained by roughage level since cows on both treatments consumed similar percentages of hay. Cows fed rapeseed meal consumed 55.7 per cent of their total dry matter intake as hay and cows fed faba beans consumed 56.9 per cent of their total dry matter intake as hay in the first 6 weeks of lactation. The higher percentage milk fat from cows fed faba bean rations has also been reported by Presber (1972) and by Ingalls and McKirdy (1974).

Considering percentage SNF or protein, milk from cows fed faba beans was lower during both experimental periods. For the first 16 weeks of lactation, milk from cows fed faba beans was only 1.2 and 5.7 per cent lower in SNF and protein, respectively, than for the cows fed rapeseed meal.

There was no significant difference ($P > 0.05$) in terms of DM intake per day or DE consumed per day for the first 6 or 16 weeks of lactation. However, cows on the faba bean ration consumed 18.8 and 7.7 per cent more dry matter per day and 28.8 and 17.0 per cent more DE per day than those cows fed the rapeseed meal ration in the first 6 and 16 weeks of lactation, respectively.

Feed Intake on Cubed Rations

Observations showed that cows eating well before parturition, would suddenly go off-feed three to ten days postpartum and refuse large portions or all of their feed. Some cows were not eating well even before parturition. The cows going off-feed were switched to the loose concentrate and hay ration until eating properly and then gradually given cubes. Some cows completely refused to consume the cubed rations after going off-feed. Because of these early off-feed difficulties, cows later in the lactation were started on the cubed rations.

Faba Bean Cubes Plus Concentrate and Hay

Six cows were fed faba bean cubes plus concentrate and hay. Cow no. 905 ate well before calving, consuming 4.8 kg. of cubes, 2.4 kg. of concentrate, and 3.4 kg. of hay daily with little feed refusal or weigh-back. Five days after calving, no. 905 went off-feed, refusing to eat cubes. Over a 9 week period after calving, 905 consumed an average of 2.1 kg. daily of cubes. Expected intake would have been at

Table 3

Rapeseed Meal vs. Faba Beans as a Protein Supplement

	Protein Source + Standard Error		
	Rapeseed Meal	Faba Beans	% + or - compared to Rapeseed Meal
First 6 weeks of lactation *			
Milk/day (Kg.)	28.4 $^{A+}_{-}$ 2.31	25.8 $^{A+}_{-}$ 2.31	- 9.2
FCM/day (Kg.)	24.5 $^{A+}_{-}$ 2.14	24.5 $^{A+}_{-}$ 2.14	0.0
% Fat	3.11 $^{A+}_{-}$ 0.13	3.64 $^{B+}_{-}$ 0.13	+17.0
% SNF	8.18 $^{A+}_{-}$ 0.19	7.88 $^{A+}_{-}$ 0.19	- 3.7
% Protein	3.10 $^{A+}_{-}$ 0.11	2.76 $^{A+}_{-}$ 0.11	-11.0
DM/day (Kg.)	13.3 $^{A+}_{-}$ 1.62	15.8 $^{A+}_{-}$ 1.62	+18.8
DE/day (Kg.)	40.3 $^{A+}_{-}$ 5.11	51.9 $^{A+}_{-}$ 5.11	+28.8
First 16 weeks of lactation **			
Milk/day (Kg.)	26.5 $^{A+}_{-}$ 1.58	26.0 $^{A+}_{-}$ 2.24	- 1.9
FCM/day (Kg.)	22.9 $^{A+}_{-}$ 1.26	24.5 $^{A+}_{-}$ 1.79	+ 7.0
% Fat	3.09 $^{A+}_{-}$ 0.11	3.61 $^{A+}_{-}$ 0.16	+16.0
% SNF	8.06 $^{A+}_{-}$ 0.20	7.96 $^{A+}_{-}$ 0.28	- 1.2
% Protein	2.98 $^{A+}_{-}$ 0.09	2.81 $^{A+}_{-}$ 0.13	- 5.7
DM/day (Kg.)	15.5 $^{A+}_{-}$ 1.15	16.7 $^{A+}_{-}$ 1.62	+ 7.7
DE/day (Kg.)	47.0 $^{A+}_{-}$ 3.55	55.0 $^{A+}_{-}$ 5.02	+17.0

* data based on first 6 weeks of lactation for 4 cows per treatment

** data based on first 16 weeks of lactation for 4 cows on the rapeseed meal treatment and 2 cows on the faba bean treatment.

AB means in the same row that are followed by a common supersript are not significantly different (P> 0.05).

[1] 4% FCM (Kg.) = 0.4M + 15F
where FCM = fat corrected milk
M = milk production in kg.
F = butterfat production in kg.

(Overman and Gaines, 1948)

least 18.0 kg. of cubes, 2.6 kg. of concentrate, and 3.6 kg. of hay. Over that period, cow 905 recieved 29 treatments of propylene glycol for ketosis and 4 drenchings with mineral oil.

Another cow on this treatment, no. 931, was never really eating cubes before calving. Of the 4.8 kg. per day offered before calving, cow 931 consumed 1.2 kg. daily of faba bean cubes. After calving, 931 was continuously off-feed, consuming a total of 2.5 kg. in the first 2 week period. Cow 931 was administered propylene glycol 7 times during this 2 week period. To start 931 and 905 eating again, the cubes were soaked in water or molasses, top-dressed with dried molasses, or broken up with little or no effect on intake.

Other cows such as 206 and 149 ate the cubes more readily. Cow 206 ate 4.6, 2.0, and 3.0 kg. of faba bean cubes, concentrate and hay, respectively, before calving with no feed refusals. Approximately 3 days after calving, there was some feed refusal for about 3 days and then little or no feed refusals for the remaining period on test. Cow 206 consumed 13.3 kg. of faba bean cubes, 2.0 kg. of concentrate, and 2.8 kg. of hay daily while on test. Cow 149 ate well before calving with no weigh-back. After calving, cow 149 consistently left some hay weigh-back and only occasionally left weigh-back of cubes. Intake of cow 149 was 14.6 kg. of cubes, 2.0 kg. of concentrate, and 2.4 kg. of hay. It should be noted that cows 206 and 149 were younger, smaller cows with lower milk production and feed requirements.

Two cows on this treatment were later in the lactation. Cow 123 in week 49 of lactation, consumed all feed offered daily, that is 8.6 kg. of faba bean cubes, 2.0 kg. of concentrate, and 3.0 kg. of hay. Cow 009 in week 37 of lactation, also consumed all feed offered daily.

Her intake was 13.8 kg. of cubes, 2.5 kg. of concentrate, and 2.7 kg. of hay daily over her 4 week period on test.

Rapeseed Meal Cubes Plus Concentrate and Hay

Six cows were fed rapeseed meal cubes plus concentrate and hay. After calving, cow 008 ate well for the first 10 days and then had a period of 11 days in which continuous weigh-back occurred. For the next few weeks, cow 008 consistently left weigh-back but managed to consume most of her feed. Maximum feed intake for no. 008 was 20.0 kg. daily of rapeseed meal cubes for a period of 3 1/2 days in week 9 of lactation. The average intake of feed over the 115 day feeding period was 13.8 kg. of cubes, 1.6 kg. of concentrate, and 2.5 kg. of chopped hay daily.

Another cow, no. 832, ate fairly well before calving, consuming 9.0 kg. per day of a possible 11.3 kg. of rapeseed meal cubes, but went off-feed 5 days after calving, and would not start eating cubes again. Over a 6 1/2 week period, 1 week not receiving cubes, no. 832 consumed 2.0 kg. of cubes daily when expected intake of cubes should have been around 20.0 kg. daily. When no. 832 was brought back onto feed with loose concentrate and hay, cubes were given gradually in an attempt to encourage adjustment to the ration, but with unsuccessful results. At the beginning of the off-feed period, no. 832 received propylene glycol for 2 days.

Cow 201, before calving, ate 4.4 kg. of cubes, 1.8 kg. of concentrate, and 2.8 kg. of hay daily with no feed refusals. Seven days after calving, some feed refusal was noticed, and then 14 days after calving, 201 went completely off-feed. While on test, no. 201 reached a maximum intake of 12.0 kg. per day of cubes for 2 days but only averaged 4.6 kg. daily of the rapeseed meal cubes. Cow 911 also ate well

before calving, consuming 5.0 kg. of cubes, 2.2 kg. of concentrates, and 3.2 kg. of hay daily. Two days after calving, there was some weigh-back of cubes, and then 2 weeks later for 3 days, there was weigh-back. Continuous weigh-back was noticed for 3 consecutive weeks followed by a 3 week period of little or no weigh-back. Eventually, cow 911 went off-feed. Over the 10 week period on test, cow 911 ate 15.2 kg. of cubes, 1.9 kg. of concentrate, and 2.9 kg. of hay daily.

Two cows on this treatment were later in the lactation. Cow 010, in week 44 of lactation, ate 9.3 kg. of cubes, 1.6 kg. of concentrate, and 2.4 kg. of hay daily with little or no feed refusals over her 3 week period on test. Cow 948, in week 56 of lactation, ate 10.2 kg. of cubes, 1.9 kg. of concentrate, and 2.7 kg. of hay daily with no feed refusals.

Faba Bean Cubes

There were 10 cows offered the complete cubed faba bean ration. Cow 124 ate well before calving, consuming 9.8 kg. daily of faba bean cubes. Three days after calving, there was some weigh-back for two days and at 10 days after calving, intake of cubes dropped from 16.0 kg. to 6.1 kg. per day for 2 days. For the next 30 days after calving, some weigh-back was noticed. From then until the end of the test, 124 ate well. Maximum intake for 124 was 18.0 kg. per day of faba bean cubes for 3 days occurring in week 7 of her lactation. Over a 98 day feeding period, cow 124 averaged 15.4 kg. of feed intake daily. Cow 212, before calving, consumed all cubes offered, that is 9.2 kg. daily. Continuous weigh-back was noticed for the first 3 days after calving and for parts of the next 3 1/2 weeks until cow 212 went off-feed. Cow 212 consumed 8.8 kg. of the 16.2 kg. of faba bean cubes offered daily. Cow 913, consumed 10.6 kg. daily before calving, with no feed refusals. Four days after calving,

913 went off-feed and was switched to faba bean concentrate plus hay for a week. Cow 913 was then gradually introduced to the cubes, but refused to eat and had to be switched back to concentrate plus hay permanently.

Other cows later in their lactation (Table 4), ate the faba bean cubes more readily. It should be noted that cow 009 suddenly went off-feed after eating the faba bean cubes for 3 weeks.

Rapeseed Meal Cubes

Ten cows were fed the rapeseed meal cubes. Cow no. 110 consumed all cubes offered in a 3 week period before calving. Intake was 9.7 kg. per day of the rapeseed meal cubes. This cow was transferred to the faba bean concentrate plus hay ration a few days before calving.

Cow 205, ate reasonably well before calving, consuming 8.5 kg. of the 8.9 kg. of cubes offered daily. After calving, cow 205 consumed 14.7 kg. of the 17.1 kg. offered daily. Some weigh-back was noticed from 4 to 10 days after calving, and from 14 to 20 days after calving. Cow 213 went off rapeseed meal cubes 17 days after calving. Over this period, cow 213 consumed 9.4 kg. of the 15.0 kg. of cubes offered daily.

Other cows later in their lactation (Table 4), consumed rapeseed meal cubes more readily. Cow 506 constantly left weigh-back and had to be taken off the treatment repeatedly. Few problems were noted with the other cows.

Alfalfa Cubes

Eight cows were fed alfalfa cubes of the same size as the complete cubed ration. Two of these cows, 147 and 223 were prior to parturition. Cow 147 consumed all cubes offered, that is 12.0 kg. daily in a 2 week period before parturition. Cow 223 consumed only 68.5 per cent of the 12.0 kg. offered daily before parturition. Cows 726 and 213 were in weeks 2 and 6 of their lactation, respectively. After 2 days on cubes,

cow 726 rejected all cubes offered. Cow 213 rejected all cubes offered after 3 days on the alfalfa cubes. The four remaining cows were in their middle and late lactation. Cow 931 in weeks 19 to 25 of lactation, consumed 9.7 kg. of the 10.7 kg. of alfalfa cubes offered daily. Cows 745, 506, and 834 consumed cubes for 2, 3, and 6 days, respectively, before large feed refusals forced them onto different rations.

Table 4

Feed Intake of Cows Later in Lactation

Treatment	Cow No.	Starting Week On Cubes	Kg. Expected Intake	Kg. Actual Intake
Faba bean cubes	128	23	14.7	14.3
	014	30	14.8	14.7
	016	34	16.4	16.3
	009	37	16.5	15.6
	012	43	13.7	13.4
	123	46	15.3	14.6
	948	53	16.0	16.0
Rapeseed Meal cubes	506	33	14.3	12.3
	610	34	16.5	15.7
	836	38	15.0	14.8
	010	41	15.5	15.5
	727	44	15.3	14.6
	936	45	15.6	15.4
	948	62	16.0	16.0

Complete Cubed Rations

In this study, cows past the peak of lactation ate cubes more consistently than cows earlier in the lactation. The cubed rations seemed to create fewer off-feed problems for cows later in lactation. It was noticed with cows fed cubed rations, that when going to the milking parlor and back to their stalls, these cows would constantly go to stalls which contained the conventional loose concentrate and hay ration. The

cows preferred the loose concentrate and hay ration over the cubed rations. There seemed to be little difference between the acceptance of the complete cubed rations and the cubed plus loose concentrate and hay rations. The protein source of the cubed rations had little influence on intake.

From the observations of feed intake, it seems apparent that younger smaller cows having lower production and feed requirements, consumed the cubed rations more readily than older, larger cows of higher production and feed requirements. Cows 206, 149, 205, and 008, all smaller, lower producing cows, consumed the cubed rations more consistently than the larger, higher producing cows like 905, 931, 911, and 913. Also, with most cows consuming the cubed rations, there seemed to be a peak intake of cubes around 15 to 16 kg. daily. These observations suggest that cows having large feed requirements are unable to meet their requirements with cubed rations. Further research is needed in the feeding of complete cubed rations. The feeding of cubes as only a portion (50 per cent) of the roughage intake should be studied.

Fossland and Fitch (1958) reported depraved appetities for cows fed complete pelleted rations, and Murdock (1972) reported off-feed difficulties just before or after parturition when feeding a complete cubed ration to dairy cows. Thinking that the bulk density or degree of hardness of the cubes might affect the intake, as reported by Porter et al. (1953), the cubes were sorted into varying degrees of hardness and fed to the cows but with no results. Apparently, the hardness of the cubes was not an important factor since some cows ate the hardest or softest cubes with no difficulty.

Coefficients of Apparent Digestibility

In this study, coefficients of apparent digestibility were ob-

tained for dry matter, crude protein, and gross energy on rapeseed meal and faba bean rations (Table 5). Due to the off-feed difficulties, problems were encountered at the time of the digestion trial. Where cows fed cubes were not available at their peak of lactation, other cows fed cubes later in lactation were substituted.

There were no significant differences ($P > 0.05$) between coefficients of digestibility of faba bean and rapeseed meal rations in terms of dry matter, crude protein, or gross energy (Table 5). Apparent digestibility of crude protein was consistently lower with the faba bean rations, but averaged only 4.4 per cent lower than with the rapeseed meal rations. On the average, digestibilities of dry matter and gross energy were almost equal for these rations. This data shows no detrimental effects on digestion if rapeseed meal is replaced by faba beans as the protein supplement.

Considering physical forms of the rations, dry matter coefficients were not significantly different ($P > 0.05$) between treatments. However, there was a trend for the complete cubed ration to have the lowest coefficient of digestion (62.8) and the concentrate plus hay ration to have the highest coefficient (68.5). The cubes plus concentrate and hay ration (64.9) was intermediate as compared to the concentrate and hay ration and the complete cubed ration. The complete cubed ration and the cubed plus concentrate and hay ration were 8.3 per cent and 5.3 per cent, respectively, lower in digestibility than the concentrate plus hay ration.

Crude protein values, although not significantly different ($P > 0.05$), showed the complete cubed ration to be the lowest at 68.9 per cent digestibility. The other two treatments, cubes plus concentrate

and hay, and concentrate plus hay, had coefficients of digestibility of approximately 70. The complete cubed ration was 1.6 per cent lower in digestibility of crude protein than the other two treatments. Heaney et al. (1963) found crude protein digestion depressed the least when feeding pelleted rations.

With gross energy, there was a significant difference ($P < 0.05$) between concentrate plus hay (69.4) and the complete cubed ration (62.9 per cent). The complete cubed ration was 9.4 per cent lower in digestibility than the concentrate plus hay ration. The cubes plus concentrate and hay ration (65.6 per cent) was intermediate, with a 5.5 per cent reduction in digestibility as compared with the concentrate plus hay ration.

If considering either faba beans or rapeseed meal separately, in terms of physical form offered, similar trends exist for dry matter, crude protein, and gross energy digestion coefficients. However, with rapeseed meal, there was little difference between concentrate plus hay, and cubes plus concentrate and hay for dry matter, crude protein, or gross energy coefficients.

The decreased digestion coefficients associated with dry matter and gross energy are in agreement with Alwash and Thomas (1971), Meyer et al. (1959), Moore (1964), Blaxter and McCGraham (1956), Conrad and Hibbs (1973), Heaney (1963), Greenhalgh and Reid (1973) and Johnson et al. (1964) who found digestibility to decrease with cubed or pelleted rations.

Table 5

Coefficients of Apparent Digestibility *

	Dry Matter			Crude Protein			Gross Energy		
	Faba Beans	Rapeseed Meal	Ave.	Faba Beans	Rapeseed Meal	Ave.	Faba Beans	Rapeseed Meal	Ave.
concentrate + hay	70.69	66.33	68.5^{A}	68.10	71.91	70.0^{A}	71.07	67.64	69.4^{A}
cubes + concentrate + hay	62.84	66.87	64.9^{A}	67.91	72.24	70.1^{A}	63.84	67.27	65.6^{AB}
cubes	61.96	63.55	62.8^{A}	68.43	69.35	68.9^{A}	62.82	62.92	62.9^{B}
average	65.2^{a}	65.6^{a}		68.1^{a}	71.2^{a}		65.9^{a}	65.9^{a}	

* data collected from 24 lactating dairy cows; 4 cows per treatment combination.

AB means in the same column that are followed by a common superscript are not significantly different ($P > 0.05$).

a means in the same row that are followed by a common superscript are not significantly different ($P > 0.05$).

Experiment 2 Faba Bean Acceptability

Dry Matter Intake

There was no significant difference ($P > 0.05$) in dry matter intake between treatments although there was an 11.3 per cent increase in dry matter intake at the 40 per cent level of faba beans as compared to the barley ration (Table 6). At the 20 per cent level of faba beans, dry matter intake was similar to that with the barley ration. Heifers consumed significantly more ($P < 0.05$) feed than bulls, averaging 6.86 and 5.54 kg., respectively. This difference was attributed to the heifers larger weight. At the beginning of the trial, heifers averaged 280 kg. as compared to 220 kg liveweight for the bulls. There was no significant interaction between treatment and sex, (Appendix Table C) but there was a trend for bulls to consume less feed on all treatments reflecting the smaller weight of the bulls (Table 7).

Average Daily Gain

There was no significant difference ($P > 0.05$) between treatment or sex for average daily gain. There was, however, a 6.7 per cent increase in average daily gain when 20 per cent faba beans was compared to barley, and a 14.4 per cent increase when the 40 per cent faba bean ration was compared to the barley ration. The treatment-sex interaction was not significant ($P > 0.05$), but in all cases, except the barley ration, bulls had higher rates of gain than heifers (Table 6). On the barley treatment, bulls gained 40 per cent less than the heifers. This reduced gain could be due to feed requirements of the bulls not being met by the barley ration (Table 7).

Feed Conversion Efficiency for Dry Matter and Digestible Energy

Feed conversion efficiency was measured in terms of dry matter

intake (DM) and digestible energy (DE) consumed per unit gain. No significant differences ($P > 0.05$) were observed between treatments or sex or treatment-sex interaction (Table 6) for either DM or DE per unit gain. In terms of DM per unit gain, barley was the highest at 6.89 followed by the 40 per cent faba bean ration at 6.50 and the 20 per cent faba bean ration at 6.21 kg. DM per kg. gain. Heifers consumed 20 per cent more DM per unit gain than bulls (Table 6). This difference would be due to the larger weight of the heifers resulting in higher maintenance requirements. With the barley ration, heifers and bulls had feed conversion values of 6.37 and 7.42, respectively. This difference would be due to the smaller average daily gain of the bulls than the heifers on the barley ration.

With respect to DE per unit gain, differences between treatments, although not significant, ($P > 0.05$) showed a 13.9 per cent and a 14.4 per cent improvement in feed conversion efficiency for rations containing 20 per cent and 40 per cent faba beans, respectively, over the barley ration. DE per unit gain for heifers and bulls was 23.55 and 19.61, respectively, a 16.7 per cent reduction for bulls. This reduction is in agreement with DM per unit gain. The treatment-sex interaction for DE per unit gain was similar to DM per unit gain with the barley ration; bulls had a higher value, 26.25 as compared to 22.40 for heifers. This difference was due to the smaller average daily gain of the bulls over the heifers on the barley ration.

There were no trends or significant differences ($P > 0.05$) in terms of feed value when seed or feed faba beans were fed to growing heifers or bulls.

From the data available, the inclusion of faba beans to a

barley ration increased dry matter intake and average daily gain and improved feed conversion efficiency for growing heifers and bulls. High levels of faba beans, 40 per cent of the ration, were not detrimental, resulting in good acceptability, as judged by feed intake and growth rate. The 20 per cent faba bean ration was adequate in protein and energy for reasonable production. Antoni (1964) and Huber (1972) found calves older than 3 months of age to produce good results with rations containing 20 per cent faba beans.

Table 6

Results of Treatments and Sex for Growing Bulls and Heifers

Treatment	DM Intake (Kg./day)	Average Daily Gain (KG./day)	DM/Kg. Gain	DE/Kg. Gain
Barley	5.91	0.90	6.89	24.3
+ 20% feed faba	5.95	0.94	6.38	21.5
+ 20% seed faba	5.98	0.99	6.04	20.4
+ 40% feed faba	6.64	1.07	6.25	20.1
+ 40% seed faba	6.51	0.99	6.75	21.6
standard error	0.548	0.088	0.642	2.229
Sex				
Heifer	6.86	0.99	7.06	23.6
Bull	5.54	0.96	5.87	19.6
standard error	0.347	0.055	0.406	1.409

Table 7

Ration Analysis and Requirements and Energy Intake by Growing Bulls and Heifers

Analysis	Barley	+20% Feed Faba	+20% Seed Faba	+40% Feed Faba	+40% Seed Faba
CP (%)[1]	13.0	15.9	15.9	18.8	18.8
DE (Mcal/g)[2]	3.26	3.07	3.07	2.89	2.89

Requirements (NRC, 1971)	CP (%)	Energy (DE/DAY)
Bull (250 kg. @ 1.05 kg./day ADG)	12.2	19.8 Mcal.
Heifer (300 kg. @ 1.00 kg./day ADG)	12.2	23.8 Mcal.
Average	12.2	21.8 Mcal.

Energy Intake (Mcal. DE/DAY)	Barley	+20% Feed Faba	+20% Seed Faba	+40% Feed Faba	+40% Seed Faba
Bull	17.6	16.8	18.1	20.7	19.2
Heifer	24.2	23.4	22.5	22.0	22.6
Average	20.9	20.1	20.3	21.4	20.9

[1] based on laboratory analysis: barley 13.0%, faba beans 27.5% CP.

[2] (Crampton and Harris, 1969).

SUMMARY

Experiment 1

Before parturition, most cows ate the cubes well. Five to ten days postpartum, most cows would go off-feed and have to be switched to loose concentrate and hay rations to regain feed intake. Cows going off-feed were encouraged to consume the complete cubes by soaking the cubes in water or molasses, top-dressing the cubes with dried molasses, or by breaking up the cubes, but with little or no effect on intake. Because of these off-feed periods, several cows became ketotic and were administered propylene glycol. Cows later in their lactation ate the cubed rations more readily than cows earlier in their lactation.

It seemed apparent that younger, lower producing cows with lower feed requirements ate the cubes more consistently than older, higher producing cows with higher feed requirements. Maximum consistent intake of cubed rations was approximately 15 to 16 kg. daily. Cows preferred the loose concentrate and hay rations to the cubed rations. When going to the milking parlor and back to their stalls, cows fed cubes would go to stalls containing the rations of loose concentrate and hay.

Apparent digestibility coefficients for dry matter and gross energy were lowest from cows fed cubed rations and highest from cows fed loose concentrate plus hay. The crude protein digestibility coefficients were similar for loose concentrate plus hay and cubes plus concentrate and hay. The complete cubed ration had the lowest digestibility coefficient for crude protein. The effects of the cubed rations were probably due to the increased rate of passage of material through the rumen, decreasing digestibility.

There was no difference in milk production as measured by actual or 4 per cent FCM with cows fed either rapeseed meal or faba bean concentrate plus hay. There was however, a 16.8 per cent increase in percentage fat in milk from cows fed faba beans over those fed rapeseed meal. The reason for this observation is unknown since crude fibre levels were slightly lower with the faba bean ration, and both groups of cows consumed equal portions of their ration as roughage. Percentage SNF and protein, although not different, tended to be higher in milk from the cows fed rapeseed meal.

Experiment 2

On the faba bean acceptability trial, there were no trends favoring seed or feed grade faba beans as seen by the traits measured. There were no significant differences reflected in DM intake per day, average daily gain, or feed conversion efficiency for DM or DE. However, there was a trend favoring increased intake and gain as the level of faba beans in the ration increased. DM and DE consumed per unit gain were lowest for the 20 and 40 per cent levels of faba beans, and highest for the barley ration. For the 20 and 40 per cent faba bean rations, DE per unit gain was improved by 13.9 and 14.4 per cent, respectively.

There was a difference between sex as reflected by DM intake per day. Heifers consumed more feed than the bulls and gained slightly more than the bulls. However, feed conversion efficiency was in favor of the bulls. The heifers, because of their larger size, probably utilized more energy for maintenance than the bulls.

There were no treatment-sex interactions. However, the bulls tended to consume less feed than the heifers in all treatments, reflecting the smaller weight of the bulls. Average daily gain was greater for

the bulls on all treatments except the barley ration where gain was 40 per cent lower for the bulls than the heifers. The reason could be that feed requirements for the bulls were not being met by the barley ration. Feed conversion efficiency was highest for the bulls on the barley ration, probably due to their lower average daily gain.

CONCLUSIONS

1. Cows within 2 weeks to a month after parturition will not readily consume cubed rations.

2. Some cows of high feed requirements could not consume enough cubes early in their lactation to satisfy feed requirements.

3. Cows prefer the conventional loose concentrate plus hay rations over the cubed rations.

4. Cubed rations have a lower digestibility for dry matter and gross energy than conventional loose concentrate plus hay rations.

5. There is no difference between digestibility of rapeseed meal or faba bean rations fed to lactating dairy cows.

6. Milk production can be maintained on rations containing faba beans as a protein source.

7. Faba beans can result in increased milk fat percentage.

8. There was no difference between feed and seed grade faba beans in terms of performance of growing bulls and heifers.

9. Faba beans are readily acceptable for growing bulls and heifers.

10. Faba beans can be fed at levels as high as 40 per cent of the ration with no detrimental effects.

BIBLIOGRAPHY

Aherne, F. X. 1974. Faba beans as a protein supplement. 53rd Annual Feeders Day Report, Agriculture Bulletin. Univ. of Alberta. Summer. p. 53 - 54.

Alwash, A. H. and P. C. Thomas. 1971. The effect of the physical form of the diet and the level of feeding on the digestion of dried grass by sheep. J. Sci. Fd. Agriculture 22: 611 - 615.

Antoni, J. 1964. "Ober die Verfutterung von Ackerbohnen." Forschungsanstalt Braunschweig-Volkenrode; Kali-Briefe, Fachgeb. 13: 1.

Asplund, J. M. 1961. Rapeseed oil meal for dairy cattle. 40th Annual Feeders Day Report. Univ. of Alberta. p. 18 - 19.

Asplund, J. M. 1962. Rapeseed oil meal for dairy cattle on pasture. 41st Annual Feeders Day Report. Univ. of Alberta. p. 6.

Association of Official Agricultural Chemists. 1965. Official Methods of Analysis. 10th edition. Washington, D.C.

Aughtry, J. D. 1971. Coarse dehy for western feedlot rations. Feedstuffs 43 (32): 22.

Balch, C. C., S. Bartlett and V. W. Johnson. 1951. Apparatus for the separate collection of faeces and urine from cows. J. Agric. Sci. 41: 98 - 101.

Beardsley, D. W. 1964. Symposium on forage utilization: Nutritive value of forage as affected by physical form. Part 2. Beef cattle and sheep studies. J. Anim. Sci. 23: 239 - 247.

Bishop, S. E., J. K. Loosli, G. W. Trimberger, and K. L. Turk. 1963. Effects of pelleting and varying grain intakes on milk yield and composition. J. Dairy Sci. 46: 22 - 26.

Blaxter, K. L. and N. McCGraham. 1956. The effect of the grinding and cubing process on the utilization of the energy of dried grass. J. Agric. Sci. 47: 207 - 217.

Bletner, J. K., N. E. Chalhoub, and O. E. Goff. 1963. The horsebean (Vicia faba L.) as a vegetable protein concentrate in chick diets. Poultry Sci. 42: 562 - 568.

Bringe, A. N., R. P. Niedermeier, H. J. Larson and H. Bruhn. 1958. Comparison of long hay, large size pellets, and field baled legume hay for dairy cows. J. Anim. Sci. 17: 1164 (abstr.).

Brooks, O. L., W. J. Miller, E. R. Beaty and E. M. Clifton. 1962. Performance of dairy cows fed pelleted and baled coastal bermuda grass and alfalfa hay. J. Dairy Sci. 45: 1188 - 1191.

Burgess, P. L. and J. W. G. Nicholson. 1971. Performance of lactating cows fed rations containing soybean meal, rapeseed meal and urea. Proc. Can. Soc. Anim. Sci. May 18.

Carpenter, K. J. and C. L. Johnson. 1968. The metabolizable energy of field beans (Vicia faba L.) for poultry. J. Agric. Sci. 70: 391 - 392.

Castle, E. J. 1956. The rate of passage of foodstuffs through the alimentary tract of the goat. Br. J. Nutr. 10: 15 - 23.

Chomyszyn, M. and R. Beza. 1965. Untreated and treated rapeseed oilmeal for feeding cows. Zakt. Hodow. Doswiad. Zwierzat PAN Biul No. 9: 71 - 78.

Clarke, H. E. 1970. The evaluation of the field bean (Vicia faba L.) in animal nutrition. Nutrition Society Proceedings 29: 64 - 73.

Conrad, H. R. and J. W. Hibbs. 1973. Coarse alfalfa pellets substitute for hay. Feedstuffs. 45(6): 56 - 61.

Conrad, H. R., A. D. Pratt and J. W. Hibbs. 1964. Regulations of feed intake in dairy cows. I. Change in importance of physical and physiological factors with increasing digestibility. J. Dairy Sci. 47: 54 - 62.

Crampton, E. W. and L. E. Harris. 1969. Applied Animal Nutrition. 2nd edition. W. H. Freeman and Company, San Francisco.

Dinius, D. A. and B. R. Baumgardt. 1970. Regulation of food intake in ruminants. 6. Influence of caloric density of pelleted rations. J. Dairy Sci. 53: 311 - 316.

Eden, A. 1968. Field beans in stock feeding. Agriculture. 75: 209 - 212.

Edwards, D. G. and I. F. Duthie. 1970. Metabolizable energy values for broiler chicks of eleven samples of field beans (Vicia faba L.) harvested in 1968. J. Agric. Sci. 76: 257 - 259.

Edwards, D. G. and I. F. Duthie. 1972. A short note on the metabolizable energy values of broiler chicks of two varieties of field beans (Vicia faba L.) harvested in 1969. J. Agric. Sci. 79: 169 - 170.

Edwards, D. G., I. F. Duthie, B. M. Rogers, and E. Owen. 1973. A note on the digestibility by sheep of hulls from the field bean (Vicia faba L.). Anim. Prod. 17: 329 - 332.

Feedstuffs. 1973. Complete cubed hay rations reduce milk fat, Dairy Meet told. Feedstuffs. 45(28): 4.

Fossland, R. G. and J. B. Fitch. 1958. Use of pellets made from finely ground alfalfa in dairy rations. J. Dairy Sci. 41: 1484 (abstr.)

Franck, undated. "Ackerperle Anbau und Verwertung." Technical leaflet: Saatzuchtwirtschaft Dr. Franck. Overlimpurg.

Golding, N. S. 1964. A new method for estimating total solids and solids-not-fat in milk and liquid milk products by hydrometric means. Washington Agri. Exp. Sta., Bull. 650. p. 1 - 24.

Greenhalgh, I. F. D. and G. W. Reid. 1973. The effects of pelleting various diets on intake and digestibility in sheep and cattle. Anim. Prod. 16: 223 - 233.

Grenet, N. 1970. Utilisation du tourteau de Colza Pour l'Alimentation des ruminants principaux resultats. Journees Internationales sur le colza: Exposes et Discussions. Centre Technique Interprofessionnel des Oleagineux Metropolitain. p. 542 - 546.

Grieve, C. M. 1973. Rapeseed meal for lactating dairy cows. Univ. Alberta. 52nd Annual Feeders Day Report. p. 33 - 34.

Haenlein, G. F. W. and R. D. Holdren. 1965. Response of sheep to wafered hay having different physical characteristics. J. Anim. Sci. 24: 810 - 818.

Hawkins, G. E., G. E. Paar and J. A. Little. 1963. Physiological responses of lactating dairy cattle to pelleted corn and oats. J. Dairy Sci. 46: 1073 - 1080.

Heaney, D. P., W. J. Pigden, D. J. Minson and G. L. Pritchard. 1963. Effect of pelleting on energy intake of sheep from forage cut at three stages of maturity. J. Anim. Sci. 22: 752 - 757.

Homb, T., I. Ørud, and T. Woldern. 1958. Experiments with rapeseed meal for dairy cows. Tidsskr. norske Landbruk. 65: 253 - 264.

Homb, T., I. Ørud, and T. Woldern. 1961. Three years' trial on feeding ground rapeseed to dairy cattle. Norges Landbrukshogsk. Foringsforsok Beretn No. 103: 31.

Huber, F. 1972. "Die Ackerbohne als Futtermittel." Mitteil. f. d. Schweiz. Landwirtsch. Nr. 2. p. 25 - 29.

Hutton, G. A. Jr., M. Ronning and J. B. Dobie. 1964. High and low moisture content alfalfa wafers compared to baled hay for milk production. J. Dairy Sci. 47: 156 - 159.

Ingalls, J. R. and J. A. Mckirdy. 1974. Faba beans as a substitute for soybean meal or rapeseed meal in rations for lactating cows. Can. J. Anim. Sci. 54: 87 - 89.

Ingalls, J. R., M. E. Seale and J. A. Mckirdy. 1968. Effect of rapeseed meal and urea on ad libitium consumption of grain rations by dairy cows. Can. J. Anim. Sci. 48: 437 - 442.

Ingalls, J. R. and D. E. Waldern. 1972. Rapeseed meal in rations for dairy cattle. Canadian Rapeseed Meal in Poultry and Animal Feeding. Rapeseed Association of Canada. p. 24 - 27.

Ingalls, J. R., D. E. Waldern and J. B. Stone. 1970. Rapeseed meal in ruminant rations — dairy cattle. Proceedings International Rapeseed Conference, St. Adele, Quebec, Canada. Rapeseed Association of Canada. p. 281 - 291.

Interim Report to ARC. 1974. Nutritional value of rapeseed oil meal in the diet of ruminant animals. Grant No. AG 8/134.

Jarl, F. 1951. Experiments on the feeding of Swedish rapeseed oil meal to dairy cows. Kgl. Lantbrukshogsk. Stat. Husdjursforsok Medd. 45: 42.

Johnson, R. R., G. E. Ricketts, E. W. Klosterman and A. J. Moxon. 1964. Studies on the utilization and digestion of long, ground, and pelleted alfalfa and mixed hay. J. Anim. Sci. 23: 94 - 99.

Jones, G. M. 1972. Chemical factors and their relation to feed intake regulation in ruminants. A review. Can. J. Anim. Sci. 52: 207 - 239.

Jorgensen, N. A. and L. H. Schultz. 1963. Ration effects on rumen acids, ketogenesis, and milk composition. I. Unrestricted roughage feeding. J. Dairy Sci. 46: 437 - 443.

Jorgensen, N. A., L. H. Schultz and G. R. Barr. 1965. Factors influencing milk fat depression on rations high in concentrates. J. Dairy Sci. 48: 1031 - 1039.

Keith, J. M., W. A. Hardison, J. T. Huber and G. C. Gref. 1961. The effect of the physical form on the nutritive value of hay fed to lactating dairy cows. J. Dairy Sci. 44: 1174 (abstr.).

Klopfenstein, T. and W. Schneider. 1973. Dehy as roughage in cattle finishing rations. Feedstuffs. 45(6): 52 - 53.

Macleod, N. A., A. MacDearmid and M. Kay. 1972. A note on the use of field beans (Vicia faba) for growing cattle. Anim. Prod. 14: 111 - 113.

Marquardt, R. R. and L. D. Campbell. 1973. Raw and autoclaved faba beans in chick diets. Can. J. Anim. Sci. 53: 741 - 746.

McCrosky, J. E., L. S. Pope, D. F. Stephans and G. Waller. 1961. Effect of pelleting steer fattening rations of different concentrate to roughage ratios. J. Anim. Sci. 20: 42 - 45.

Meyer, J. H., R. L. Gaskill, G. S. Stoewsand and W. C. Weir. 1959. Influence of pelleting on the utilization of alfalfa. J. Anim. Sci. 18: 336 - 346.

Meyer, J. H., W. C. Weir, J. B. Dobie and J. L. Hull. 1959b. Influence of the method of preparation on the feeding value of alfalfa hay. J. Anim. Sci. 18: 976 - 982.

Minson D. J. 1963. The effect of pelleting and wafering on the feeding value of roughage. A review. Br. Grassland Soc. J. 18: 39 - 44.

Montgomery, M. J. and B. R. Baumgardt. 1965a. Regulation of food intake in ruminants. 1. Pelleted rations varying in energy concentration. J. Dairy Sci. 48: 569 - 574.

Montgomery, M. J. and B. R. Baumgardt. 1965b. Regulation of food intake in ruminants. 2. Rations varying in energy concentration and physical form. J. Dairy Sci. 48: 1623 - 1628.

Moody, E. G. 1962. Pelleted alfalfa and coastal bermuda grass as dairy roughages. J. Dairy Sci. 45: 694 (abstr.).

Moore, L. A. 1964. Symposium on forage utilization: Nutritive value of forage as affected by physical form. Part 1. General principles involved with ruminants and effect of feeding pelleted or wafered forage to dairy cattle. J. Anim Sci. 23: 230 - 238.

Murdock, F. R. 1972. Cubed complete rations for lactating dairy cows. Proceeding of 7th Annual Pacific Northwest Animal Nutrition Conference. Portland, Oregon. Nov. 2 - 3.

Murdock, F. R. 1973. Hyperkeratosis in cows fed cubes. Symposium on Health and Management Practices for High Production. 68th Annual Meeting of American Dairy Sci. Ass'n. Pullman, Washington.

National Academy of Sciences. 1971. Nutrient requirements of domestic animals. Number 3. Nutrient requirements of dairy cattle. 4th edition. Washington, D. C.

Nitsan, Z. 1971. Vicia faba beans vs. soyabean meal as a source of protein. J. Sci. Fd. Agric. 22: 252 - 255.

Nordfeldt, S. 1958. Digestibility and feeding experiments with rapeseed and mustardseed meal of low and high fat content for dairy cows. Kungl. Lantbrukshogsk. Husdjursforsok Medd. 66: 38.

Oltjen, R. R., T. S. Rumsey and P. A. Putnam. 1971. All forage diets for finishing beef cattle. J. Anim. Sci. 32: 327 - 333.

Overman, O. R. and W. L. Gaines. 1948. Linearity of regression of milk energy and fat percentage. J. Anim. Sci. 7: 55 - 59.

Palmquist, D. L., L. M. Smith and M. Ronning. 1964. Effect of time of feeding concentrates and ground, pelleted alfalfa hay on milk fat percentage and fatty acid composition. J. Dairy Sci. 47: 516 - 520.

Porter, G. H., R. E. Johnson, H. D. Eaton, F. C. Elliott and L. A. Moore. 1953. Relative value of milk production of field cured and field baled, artificially dried-chopped, artificially dried-ground and artificially dried-pelleted alfalfa when fed as the sole source of roughage to dairy cows. J. Dairy Sci. 36: 1140 - 1149.

Presber, A. A. W. 1972. An inquiry into the origin, cultivation, and utilization of the small faba bean (horsebean) in Austria, The Federal Republic of Germany and England. Canada Grains Council Rep. October 31. p. 64.

Richter, K., K. L. Cranz and J. Antoni. 1964. "Ackerboken in der Milchviehfutterung." Das Wirtschaftseigne Futter, Heft 1. p. 91 - 97.

Ronning, M. 1960. Effect of varying alfalfa-hay concentrate ratios in a pelleted ration for dairy cows. J. Dairy Sci. 43: 811 - 815.

Ronning, M. and J. B. Dobie. 1962. Wafered vs. baled alfalfa hay for milk production. J. Dairy Sci. 45: 969 - 971.

Ronning, M., J. W. Meyer and G. T. Clark. 1959. Pelleted alfalfa hay for milk production. J. Dairy Sci. 42: 1373 - 1376.

Ross, R. H., D. L. Fourt, and F. C. Gephart. 1959. Alfalfa "hayfers" vs. baled alfalfa hay for milk and butterfat production. J. Dairy Sci. 42: 1740 - 1741 (abstr.).

Schmidt, G. H. and L. D. Van Vleck. 1974. Principles of Dairy Science. W. H. Freeman and Company Publishers. p. 93 - 94.

Seale, M. E. 1952. Univ. Manitoba 2nd Annual Livestock Day Report. p. 11.

Shaw, J. C. 1955. Progress in current research in dairy cattle. Proc. Univ. of Maryland Nutr. Conf. Feed Mfrs. p. 53.

Simkins, K. L. Jr., J. W. Suttie and B. R. Baumgardt. 1965a. Regulation of food intake in ruminants. 3. Variation in blood and rumen metabolites in relation to food intake. J. Dairy Sci. 48: 1629 - 1634.

Simkins, K. L. Jr., J. W. Suttie and B. R. Baumgardt. 1965 b. Regulation of food intake in ruminants. 4. Effect of acetate, propionate, butyrate, and glucose on voluntary food intake in dairy cattle. J. Dairy Sci. 48: 1635 - 1642.

Smillie, K. W. 1969. Statpack 2: An APL Statistical Package 2nd edition. Publ. no. 17. Dept. Computing Sci. Univ. of Alberta. Edmonton, Alberta.

Smillie, K. W. 1969. Some APL Algorithms for Orthogonal Factorial Experiments. Publ. no. 18. Dept. Computing Sci. Univ. of Alberta. Edmonton, Alberta.

Stahlin, A. 1957. "Handbuch der Landwirtschaftlichen Versuchs-und Untersuchungsmethodik; II. Teil: Die Beurteilung von Futtermitteln." Neumann Verlag, Radebeul und Berlin.

Steel, R. G. D. and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., New York.

Summers, C. E. 1962. The application of science to ruminant nutrition. Pelleted rations for beef cattle. Iowa State Univ. of Sci. and Tech. AH-843.

Tayler, J. C. 1970. Dried forages and beef production. Br. Grassld. Soc. J. 25: 180 - 190.

Tetlow, R. M. and R. J. Wilkins. 1972. The influence of package size and density on the intake of dried grass wafers fed to lambs. Anim. Prod. 14: 335 - 341.

Thomas, G. D., E. E. Bartley, H. B. Pfost and R. M. Meyer. 1968. Feed processing III. Effects of ground, steam heated, and pelleted hay, with and without pelleted grain on milk composition and rumen volatile fatty acid ratios. J. Dairy Sci. 51: 869 - 875.

Tigges, L. and G. M. Ward. 1959. Milk and butterfat production from mash and pelleted grain ratios. J. Dairy Sci. 42: 1741 (abstr.).

Van Soest, P. J. 1963. Ruminant fat metabolism with particular reference to factors affecting low milk fat and feed efficiency. A review. J. Dairy Sci. 46: 204 - 216.

Veltman, B. I., J. W. Thomas and J. Molitorisz. 1962. Comparative acceptability of wafered and baled alfalfa hay for dairy animals. J. Dairy Sci. 45: 694 (abstr.).

Vidacs, G. and G. M. Ward. 1960. Parakeratosis condition of rumen epithelium produced by an all concentrate ration. J. Dairy Sci. 43: 875 (abstr.).

Wainman, F. W., K. L. Blaxter and J. S. Smith. 1972. The utilization of the energy of artificially dried grass prepared in different ways. J. Agric. Sci. 78: 441 - 447.

Waldern, D. E. and G. Cedeno. 1970. Comparative acceptability and nutritive value of barley, wheat mixed feed and a mixed concentrate ration in meal and pelleted forms for lactating cows. J. Dairy Sci. 53: 317 - 324.

Wallace, J. D., R. J. Raleigh and W. A. Sawyer. 1961. Utilization of chopped, wafered, and pelleted native meadow hay by weaned Hereford calves. J. Anim. Sci. 20: 778 - 781.

Weingardt, R. 1973. Analysis of variance C. S. 2384 (ANOFPR). Univ. of Alberta, Computing Service, Edmonton, Alberta.

Whiting, F. 1965. Rapeseed meal for milk production. Rapeseed meal for livestock and poultry. A review. Canada Dept. Agriculture. p. 63 - 66.

Wilkins, R. J., C. R. Lonsdale, R. M. Tetlow and T. J. Forrest. 1972. The voluntary intake and digestibility by cattle and sheep of dried grass wafers containing particles of different size. Anim. Prod. 14: 177 - 188.

Witt, M., F. W. Huth and W. Hartmann. 1959. Rapeseed meal a valuable feedstuff for dairy cattle. Ztschr. Tierphysiol. Tierernahrung Futtermittelk. 14: 175 - 185.

Appendix Table A

Mean squares obtained by analysis of variance (Experiment 1)

Variable	Source of Variation	Degrees of Freedom	Mean Squares
Apparent digestible dry matter (%)	Protein source	1	1.046
	Physical form	2	67.753
	Protein X Physical	2	37.291
	Error	18	27.287
	Total	23	
Apparent digestible crude protein (%)	Protein source	1	54.813
	Physical form	2	3.540
	Protein X Physical	2	6.733
	Error	18	26.713
	Total	23	
Apparent digestible gross energy (%)	Protein source	1	0.007
	Physical form	2	84.924*
	Protein X Physical	2	23.501
	Error	18	22.512
	Total	23	
Rapeseed meal concentrate versus Faba bean concentrate (6 week period)			
Dry Matter Intake/ Day (Kg.)	Concentrate	1	12.5
	Error	6	10.53
	Total	7	
Digestible Energy Intake/Day (Kg.)	Concentrate	1	267.961
	Error	6	104.426
	Total	7	
Milk Production/ Day (Kg.)	Concentrate	1	13.005
	Error	6	21.318
	Total	7	
4%FCM/Day	Concentrate	1	0.005
	Error	6	18.359
	Total	7	
% Milk Fat	Concentrate	1	0.567*
	Error	6	0.067
	Total	7	
% Milk SNF	Concentrate	1	0.186
	Error	6	0.151
	Total	7	

Variable	Source of Variation	Degrees of Freedom	Mean Squares
% Milk Protein	Concentrate	1	0.235
	Error	6	0.044
	Total	7	
Rapeseed meal concentrate versus Faba bean concentrate (16 week period)			
Dry Matter Intake/ Day (Kg.)	Concentrate	1	2.083
	Error	4	5.263
	Total	5	
Digestible Energy Intake/Day (Kg.)	Concentrate	1	85.333
	Error	4	50.469
	Total	5	
Milk Production/ Day (Kg.)	Concentrate	1	0.403
	Error	4	10.031
	Total	5	
4% FCM/Day	Concentrate	1	3.413
	Error	4	6.374
	Total	5	
% Milk Fat	Concentrate	1	0.364
	Error	4	0.050
	Total	5	
% Milk SNF	Concentrate	1	0.014
	Error	4	0.157
	Total	5	
% Milk Protein	Concentrate	1	0.042
	Error	4	0.038
	Total	5	

* ($P < 0.05$)

Appendix Table B

Mean squares obtained by analysis of variance (Experiment 2)

Variable	Source of Variation	Degrees of Freedom	Mean Squares
Average Daily Gain (Kg.)	Sex	1	0.00392
	Treatment	4	0.01748
	Sex X Treatment	4	0.05658
	Error	10	0.03065
	Total	19	
Dry Matter Intake/ Day (Kg.)	Sex	1	8.6724 *
	Treatment	4	0.48391
	Sex X Treatment	4	0.38466
	Error	10	1.2018
	Total	19	
Digestible Energy/ Kg. Gain	Sex	1	77.618
	Treatment	4	11.223
	Sex X Treatment	4	21.565
	Error	10	19.864
	Total	19	
Dry Matter/ Kg. Gain	Sex	1	7.1401
	Treatment	4	0.5022
	Sex X Treatment	4	1.7514
	Error	10	1.6464
	Total	19	

* ($P < 0.05$)

Appendix Table C

Treatment - Sex Interaction (Experiment 2)

Variable	Treatment	Sex	
		Heifer	Bull
Dry Matter Intake/ Day (Kg./day)	Barley	6.88	4.95
	20% feed faba	6.90	5.01
	20% seed faba	6.63	5.34
	40% feed faba	6.87	6.42
	40% seed faba	7.03	5.99
Average Daily Gain (Kg./day)	Barley	1.12	0.67
	20% feed faba	0.92	0.96
	20% seed faba	0.96	1.02
	40% feed faba	1.02	1.13
	40% seed faba	0.94	1.05
Dry Matter/ Kg. Gain	Barley	6.37	7.42
	20% feed faba	7.54	5.23
	20% seed faba	6.91	5.17
	40% feed faba	6.81	5.69
	40% seed faba	7.68	5.83
Digestible Energy/ Kg. Gain	Barley	22.4	26.3
	20% feed faba	25.5	17.5
	20% seed faba	23.4	17.5
	40% feed faba	21.8	18.3
	40% seed faba	24.7	18.6

Appendix Table D

Faba Bean Composition*

COMPONENT	LEVEL
Dry Matter	88.16%
Gross Energy	3913 cal/gm.
Crude Protein	27.47%
Fat	0.87%
Crude Fibre (acid base)	8.6%
Calcium	0.08%
Phosphorus	0.49%

*Laboratory analysis